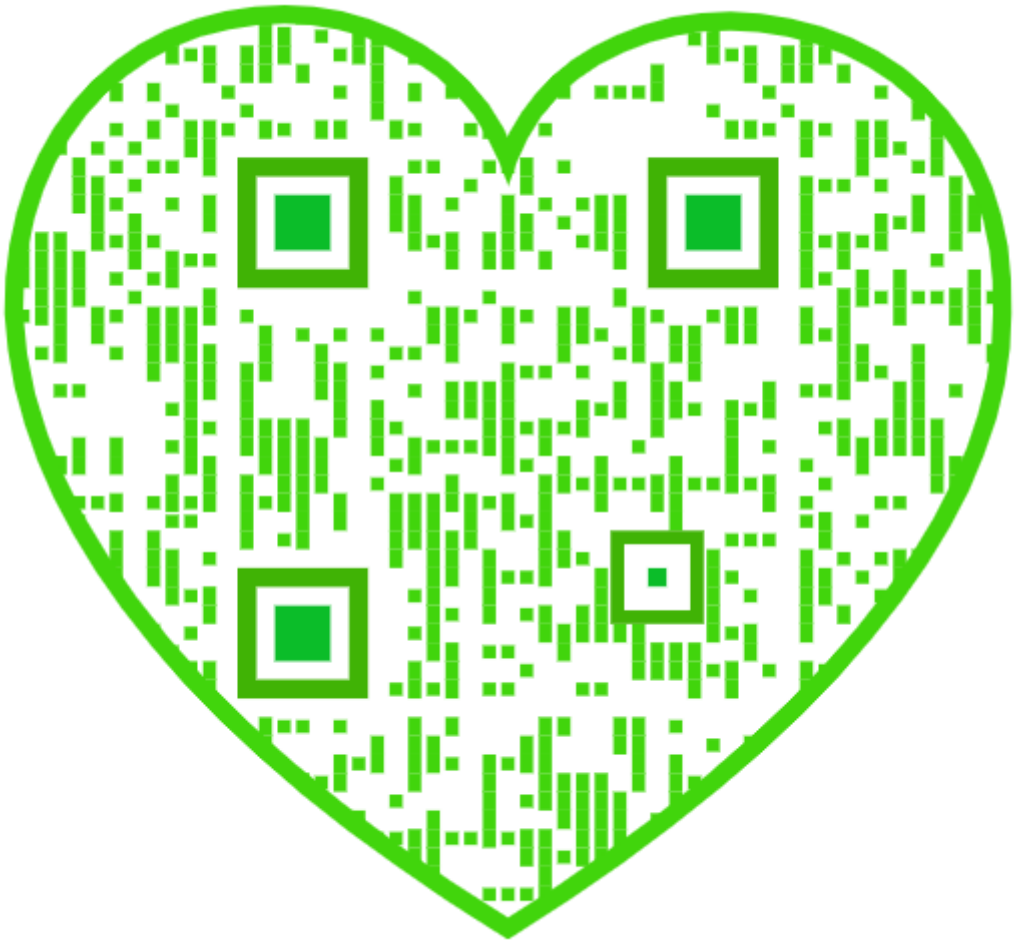

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The Motor Cycle Handbook

The Construction, Operation, Care and Repair of Modern Types of Motor Cycles, Their Accessories and Equipment.

By

HAROLD P. MANLY

Author of "Automobile Upkeep and Care," "The Ford Motor Car and Truck," "Automobile Ignition" and "Automobile Starting and Lighting." Editor of "Brookes' Automobile Handbook."

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PREFACE

The Motor Cycle Handbook is a manual covering the construction, the operating principles, the care and the repair of the newer types of machine. Single-cylinder, two-cylinder V-type, two-cylinder opposed and four-cylinder engines are treated in detail and two-cycle construction has received full consideration. Especial attention has been given to modern designs in the multi-speed transmission, and the various developments in driving clutches and their controls.

The electrical sections will be found complete; covering the ignition system in both magneto and battery types as well as giving full descriptions of the important dynamo and storage battery lighting equipments.

In common with the other volumes in this series, but little space has been given to historical and theoretical discussion. In almost all cases the principles upon which the units operate have been explained by reference to parts used in everyday construction by well known makers so that the reader will be made familiar with the work as actually carried out.

Methods of repair and adjustment have received the greatest consideration in view of the fact that these branches of motor cycle work differ materially from the corresponding operations as usually performed in automobile work. The chapter on repairs outlines the cautions that should be observed in handling the engine parts to secure the best results, while

units outside of the engine have been considered from this standpoint in their respective sections of the book.

Acknowledgment is made of the assistance extended to the author by the motor cycle manufacturing trade and especial thanks are due to the Harley-Davidson Motor Company and to the Hendee Manufacturing Company for their help in insuring the practical value of the material presented.

THE AUTHOR.

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THE MOTOR CYCLE HANDBOOK

CHAPTER I

THE MOTOR CYCLE

The modern motor cycle is distinguished from its predecessors chiefly by the adoption of many features similar to standard automobile construction and design. While the early two-wheeler consisted of little more than an engine driving an ordinary bicycle, the latest developments retain little of the bicycle except the use of only two wheels. Otherwise motor cycles are miniature automobiles.

Motor cycles in general are among the finest examples of mechanical genius and skill in workmanship. The average motor cycle is a finer mechanism than the average automobile; the truth of this statement being proven by the fact that a machine weighing only about four hundred pounds will easily negotiate good, bad and indifferent roads at speeds that would wreck a car regardless of the car's greater size and apparent strength.

Few outside of the motor cycle industry realize the extreme accuracy that is used in the manufacture of these machines. The fitting of parts is gauged to within thousandths of an inch and in many cases to fractions of the thousandth. Adjustments are pro-

vided for practically every point of wear and the materials of the wearing parts are the best that modern engineering can produce.

Motor cycle repairing calls for better work than is required in handling almost any other type of automotive apparatus and it is essential that those handling this class of work thoroughly understand the functions and operating conditions of the parts which they handle.

PARTS OF THE MOTOR CYCLE

The motor cycle may conveniently be divided into three principal groups of parts; the power plant, the transmission system, and the running gear.

The power plant includes the engine with its cylinders, crankcase, pistons, connecting rods, crankshaft and so on. The engine auxiliaries which complete the power plant include the fuel system for furnishing a combustible gas, the ignition system for firing the gas, a lubrication system for preventing wear, and a cooling system for maintaining the parts at safe operating temperatures.

The transmission system begins at the engine, where it receives power. This power goes through the clutch and the gear-set, usually called the transmission, and thence to the driving wheel through chains or belts or shafts. The clutch, gear-set and drive thus make up the complete transmission.

The running gear includes the road wheels and their tires, the frame and front forks with their suspension or method of attachment to the wheels, also the suspension for the rider's seat and for the handle bars.

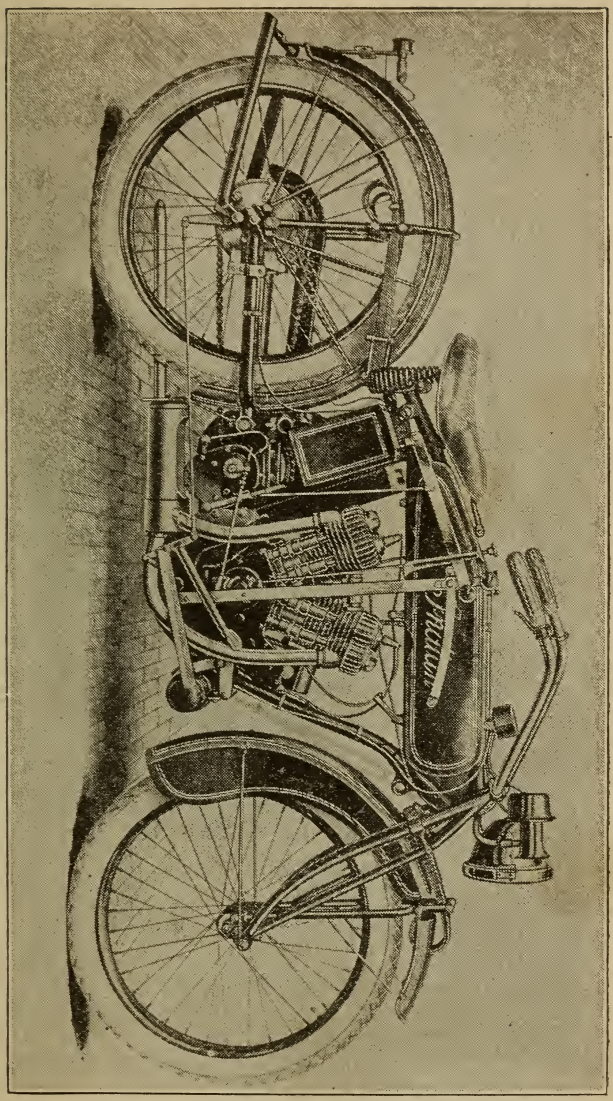

Figure 1.—Valve Side of Indian Powerplus Model.

Various control members are required in each of the three divisions. The power plant requires controls for the fuel or carburetor, for the ignition or spark, and sometimes for the oiling system as well. The transmission system includes controls for the clutch and for the various gear ratios provided in the gear-set. The running gear includes controls for the brakes, while the handle bars as steering controls might also be considered as members of this general class.

THE POWER PLANT

The Engine.—Two distinct types of engine are in use. One of these types, called the four-cycle engine, is in the majority. The four-cycle engine delivers one power impulse in each cylinder for every four strokes of the piston or two complete revolutions of the crankshaft. The other type is called a two-cycle engine and this one delivers one power impulse for each two strokes of the piston or for each revolution of the crankshaft.

Motor cycle engines differ in the number of their cylinders, most of them at present being of the two cylinder variety, while four cylinders show a gain in number of users. Single-cylinder models retain their popularity, especially in medium and light-weight machines. Most of the single-cylinder engines have their cylinders set vertically and all of the four-cylinder machines use such a mounting. Two cylinders are generally set in a "V" arrangement at an angle to each other, although in some cases these engines are of the horizontal opposed type with the two cylinders lying flat and in line with each other.

Most single and twin-cylinder engines are equipped

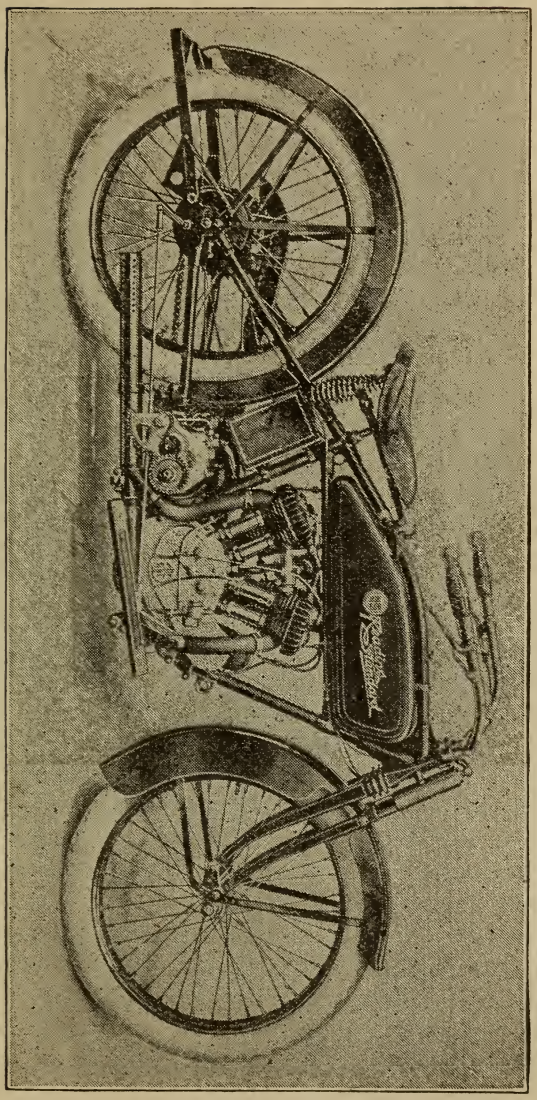

Figure 2.—Valve and Starter Side of Reading Standard.

with two flywheels, both carried inside the crankcase, but either of these types may also have an outside wheel. Four-cylinder engines generally have their single flywheel enclosed in a housing at one end of the row of cylinders, this being part of the unit power plant as often found in automobile construction.

Cooling.—American motor cycles are of the air-cooled type in which the cylinder castings are provided with a number of flanges or ribs which furnish a great amount of surface exposed to the circulation of outside air while the machine is in motion. While water cooling has been successfully employed in a number of foreign models, it has not yet gained any foothold in the United States.

Fuel System.—The chief part of this portion of the power plant is the carburetor, a device which changes the liquid fuel to a vapor and mixes this vapor with the necessary amount of air to form a combustible gas in the engine cylinders. Recent improvement and development of the carburetor has been rapid, this having been necessary in order to care for the constantly decreasing quality of the fuel available.

Aside from the carburetor the fuel system includes the supply tank with the required valves and pipe lines for making the connections between the units.

Lubrication System.—The motor cycle engine, being air-cooled, operates at a high temperature when compared with automobile engines, which are generally water-cooled. The air circulation depends on the rapidity with which the motor cycle is moving through the air, so that when pulling hard at low speed there is a decided rise in heat.

These peculiar conditions of operation make it nec-

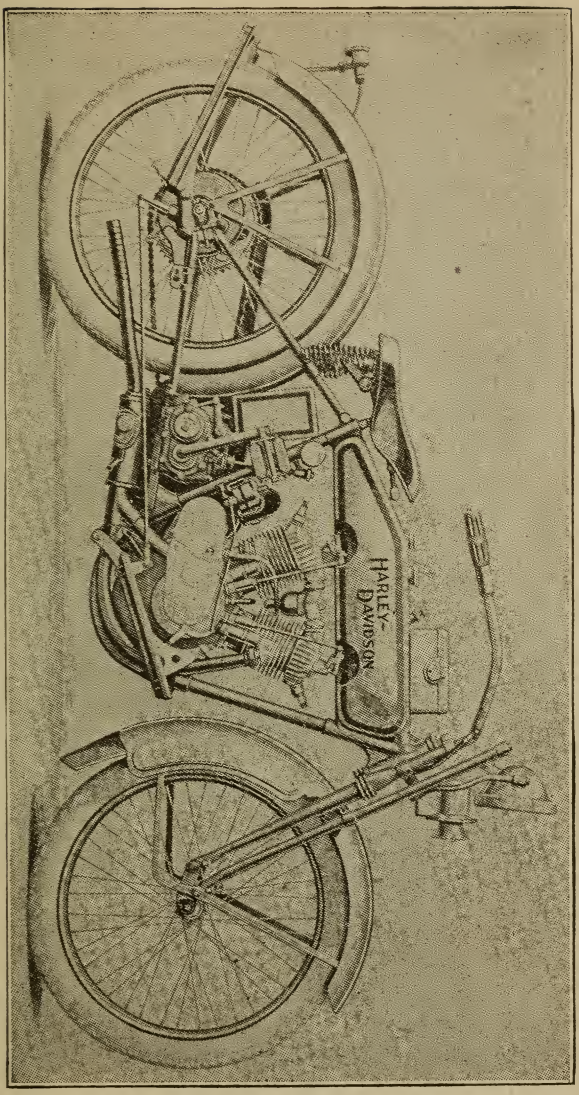

Figure 3.—Harley-Davidson Electrically Equipped Model Showing Overhead Inlet Valves.

essary that the engine lubrication or oiling system be so designed and constructed that it unfailingly supplies the requisite amount of oil to all of the moving parts under all conditions of operation.

Single and twin-cylinder engines are usually fitted with an oiling system whose supply tank is adjacent to, or a part of, the fuel tank. Four-cylinder types may carry the oil supply in the bottom of the engine crankcase or they also may be provided with a separate tank.

From the tank or oil reservoir the lubricant is delivered through a pump to the crankcase and in some cases directly to other parts of the engine mechanism. Many types of pumps are in use, some being positively driven from the engine, while others are operated by hand as the occasion may require. Engine driven pumps are generally of the plunger type, but are sometimes of the gear type in which the gear teeth force the oil through the pump. Hand pumps are of the plunger type in all cases.

Ignition System.—Electric current for producing an ignition spark may be furnished either by a dynamo which is used also for lighting purposes or by a magneto used for ignition only. Both types are in common use, the magneto still being in the majority, although the dynamo and battery system is becoming popular due to the desirability of the electric lighting which accompanies it.

The dynamo system includes the generating unit and current regulating devices, also the storage battery, all of which are common to both the ignition and the lighting system. The ignition parts include a coil for increasing the current's voltage, a breaker for causing the spark to pass at the desired time and a

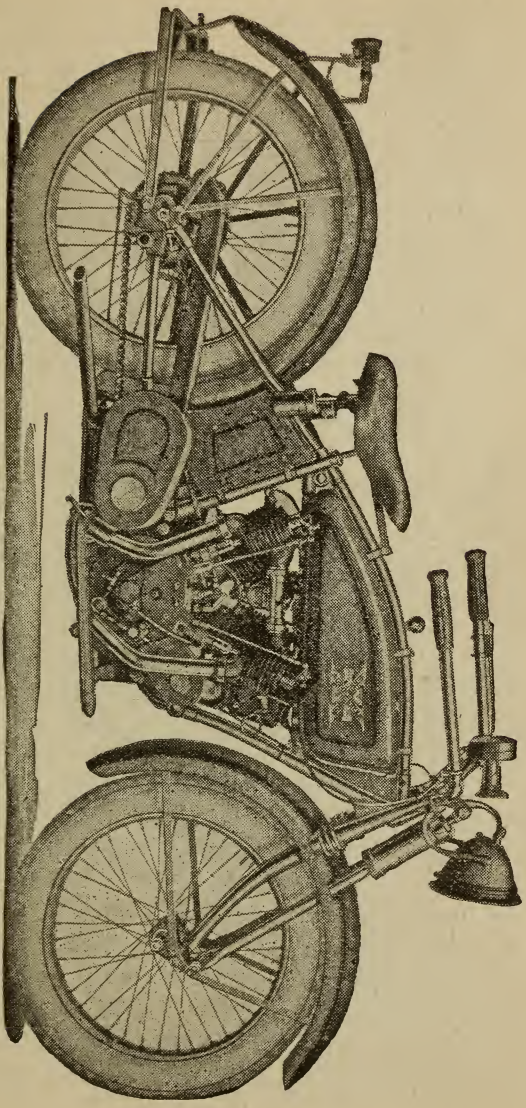

Figure 4.—Drive Side of Excelsior Showing Overhead Inlet Valves.

distributor for sending the current to the proper cylinder. In each cylinder is a spark plug between whose points or electrodes the spark passes and the ignition system is completed by the necessary wiring and switches.

The magneto system is more nearly self contained than is the battery system, inasmuch as the magneto not only generates the current but also includes within itself the breaker and distributor. Motor cycle magnetos of the true high tension variety generate the current at low voltage and then change it to a high tension or high voltage current without additional parts.

THE TRANSMISSION SYSTEM

Clutch.—The clutch enables the rider to connect the engine with the balance of the transmission system or to disconnect it at will. That is, the clutch provides a means whereby the power of the engine may be used to drive the motor cycle or by means of which the cycle may remain at a standstill while the engine still runs.

The almost universally used type of motor cycle clutch consists of a number of flat rings or disks laid flat against one another. Every other disk is connected with the engine so that it is driven when the engine runs, while the intervening disks are connected with the transmission or the drive to the wheel.

The disks are normally held pressed together by springs so that they all revolve as a unit. Under this condition the engine's power is sent to the driving parts and the clutch is said to be engaged. With the spring pressure released the disks separate and each set may revolve independently of the other set, thus

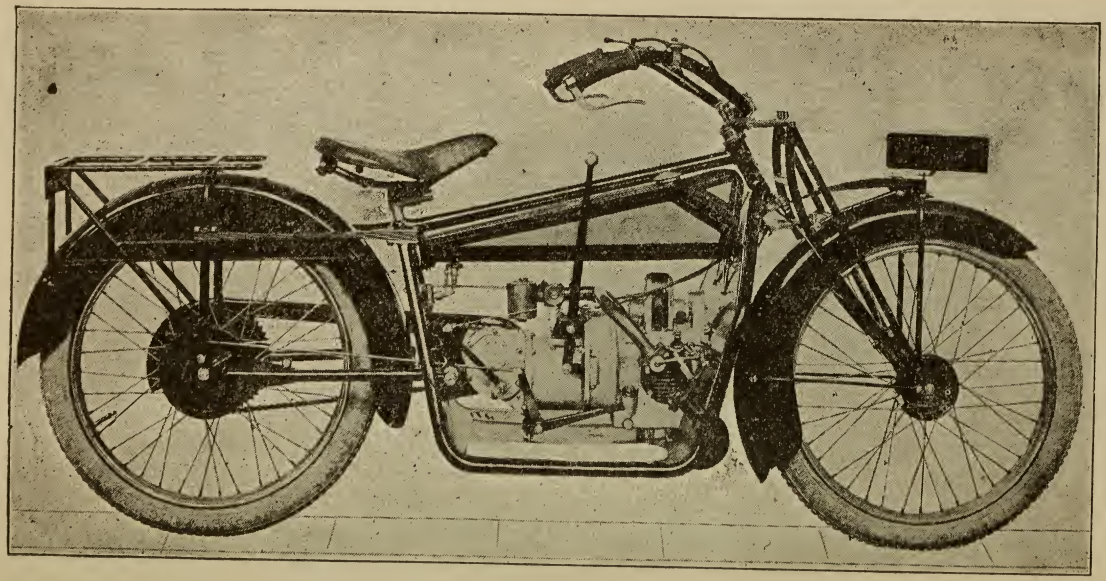

Figure 5—A. B. C. Motor Cycle With Horizontally Opposed Engine Placed Crosswise of Frame.

allowing the engine to run free with the clutch disengaged or released.

Some of these clutches operate in a bath of oil, while others allow the disks to remain dry. The clutch is carried either with the gear-set or is mounted on the engine housing. It is operated by the rider with a foot pedal, or a hand lever or grip, and in some machines by both of these control members.

The Gear-Set.—The power developed by an internal combustion engine such as used in motor cycles is in almost direct proportion to the speed at which the engine is running; that is, the greater the speed the greater will be the power. It will be recognized that under some conditions of slow running a great amount of power may be called for, this being true when driving through deep sand or mud. It is therefore desirable to provide means for operating the engine at various rates of speed while the cycle's speed remains constant, and this is accomplished by the gear-set.

The greatest number of motor cycles provide three different ratios or reductions of speed between the engine and the driving wheel. Some, however, have but a single ratio or a direct drive; others have two different ratios; while still others are fitted with three ratios for forward motion with a fourth one for driving backward or a reverse.

In the three speed machine high gear provides the least reduction of engine speed and is therefore used for ordinary driving with the motor cycle running at medium and high speeds on the road. Intermediate or second speed provides a greater reduction so that the engine can run fast enough to enable the cycle to climb steep hills or to pass over bad road condi-

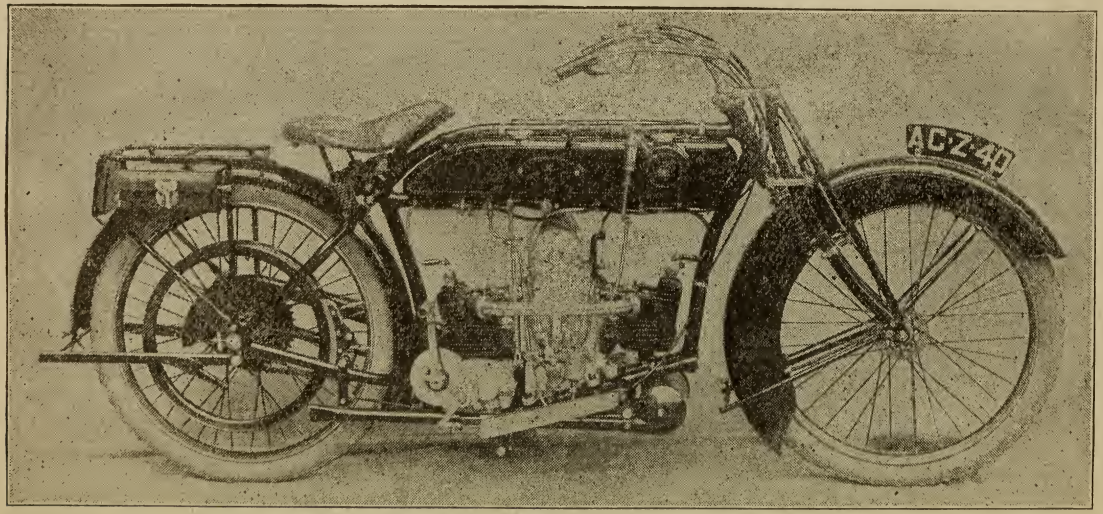

Figure 6.—Humber Machine With Horizontally Opposed Engine Placed Lengthwise of Frame.

tions. Low speed or first speed allows the engine to run ten or twelve times as fast as the road wheel turns and this ratio is used in starting from rest and for driving through extremely bad going.

The usual gear-set consists of two series of gears mounted on parallel shafts. The gears carry varying numbers of teeth so that with different pairs brought into engagement with each other, different ratios of speed are obtained between the two shafts. One shaft is connected with the engine while the other is connected with the drive to the road wheel. The speed changes are generally controlled by a hand lever which may be easily moved by the rider.

The Starter.—Whereas the old-time motor cycle was started by pedaling it along the road or else by running along side until the engine was started, almost all of the newer models are provided with what is called a "kick starter."

The starter consists of a foot pedal carried at the outer end of an arm, the arm being connected with a toothed segment or with a small gear. This segment or gear engages with another gear connected to the transmission in such a way that pressure of the operator's foot on the pedal causes the engine crankshaft to go through one or more revolutions. With the controls properly manipulated, this cranking starts the engine.

Drive.—From the preceding description it will be seen that the power generated in the engine must be carried to the gear-set and from the gear-set it must be carried to the driving wheel. The drive itself may thus be considered as of two parts in the standard type of machine; first from the engine to the gear-set, and second from the gear-set to the rear wheel.

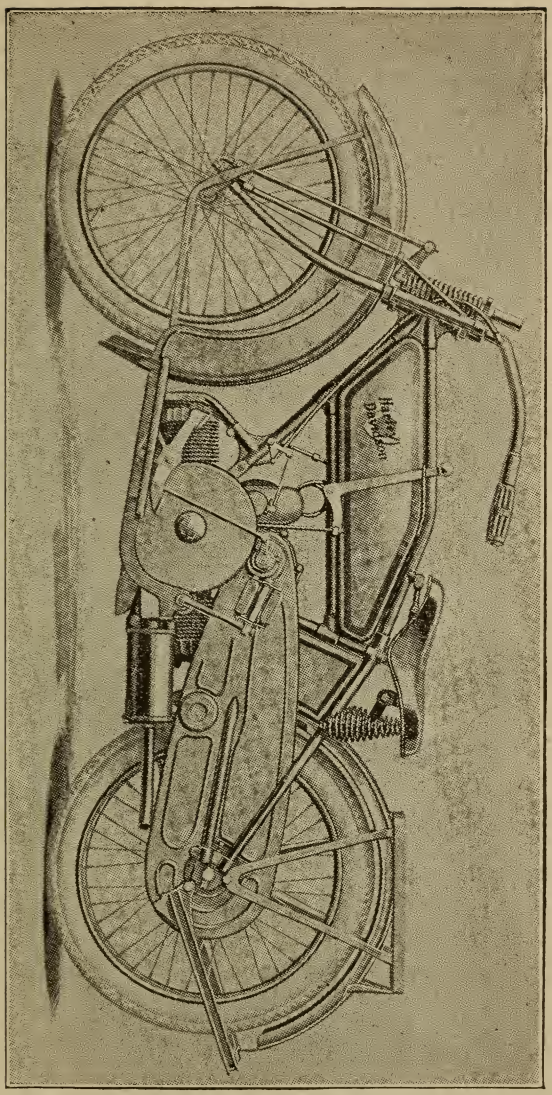

Figure 7.—Harley-Davidson Twin-Cylinder Horizontally Opposed Machine.

Chains are the means usually employed for both parts of the drive. With the engine and gear-set constructed as separate units and mounted independently of each other, chain drive is almost universal practice between these two parts. With the engine and gear-set built as a unit power plant and held in permanent alignment and relation with each other the drive between them is by means of a direct extension of the crankshaft or through bevel or worm gears.

In machines driving directly from the engine to the road wheel, this class including most of those having but a single speed ratio, the drive is usually taken through a belt either of flat or V type. Drive from the gear-set to the rear wheel is usually carried through a chain, although a belt may sometimes be used at this point.

THE RUNNING GEAR

Motor cycle frames are constructed of steel tubing and pressed steel. In general outline they bear a distinct resemblance to the ordinary diamond type of bicycle frame. They are, however, larger and stronger and are so shaped as to accommodate the engine, the gear-set, the supply tanks, and the generally heavier wheels and hubs of the motor cycle.

The front or steering wheel is carried between forks mounted in a head provided with bearings. Control of direction is through the handle bars. In a few machines the front forks are of trussed construction, but in the great majority of designs the forks include springs and are built in two parts connected by rocker levers or arms. One part is attached directly to the wheel hub while the other part is carried by the frame

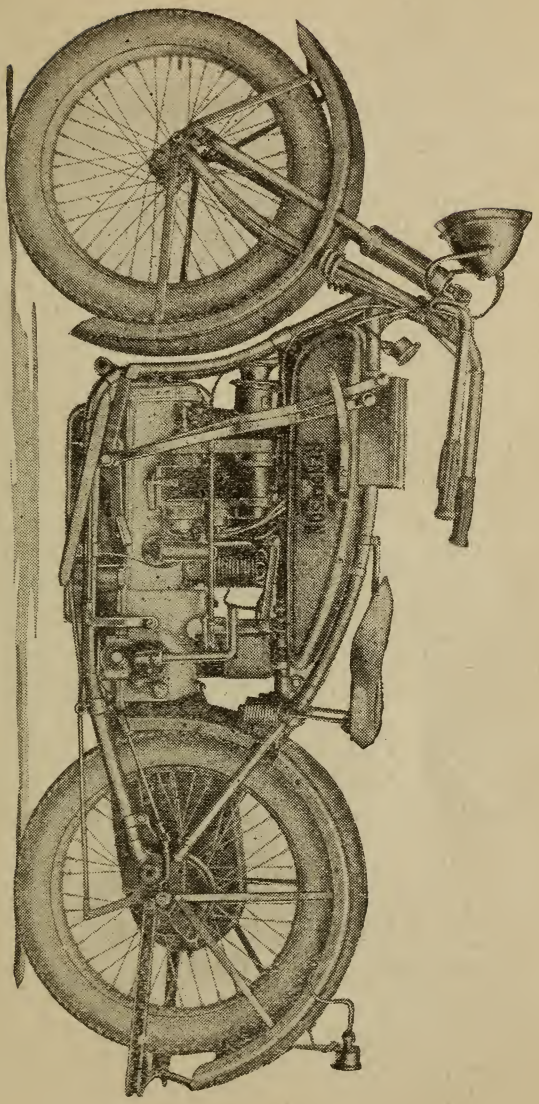

Figure 8.—Henderson Four-Cylinder Motor Cycle.

head. Relative movement between the parts is controlled by springs of either coiled or leaf type.

While the rear wheel is often carried between rigid extensions of the frame, it may also be spring mounted in some designs, leaf springs being most often used at this point. The rider's saddle is usually built with coiled springs and the saddle may be carried either by a seat post extending down into one of the frame members or it may be mounted on a bar which is pivoted at one end. Either the bar or the seat post may then be fitted with springs so that easy riding qualities are secured.

At the present time all standard motor cycle wheels are of the wire spoke type although disk wheels and wood spoke wheels have their advocates and are used to some extent. The distance between the hub of the front wheel and the hub of the rear wheel is measused as the wheelbase of the motor cycle. This distance varies between fifty and sixty-five inches, about fifty-seven inches being the average wheelbase in use.

Tire sizes are growing larger year by year. While some tire sections as small as two inches are still found, the greater number of machines carry three-inch in both front and rear and many are using three and one-half-inch tires. The outside diameter or height of the tire is usually twenty-six, twenty-seven or twenty-eight inches.

Brakes.—In American practice the brakes are placed on the rear wheel only, although many foreign machines have front wheel brakes in addition to those used on the rear. Again, the American practice attaches the brakes so that they operate directly on the rear hub or at least on drums attached to the rear hub. In many foreign designs the rear wheel brakes

act on the pulley carrying the driving belt and which is attached to the rear wheel rim or to the spokes.

The most generally used type of brake is that formed by a band contracting on a drum. Some machines use a brake constructed of internal shoes which expand within a drum while others use both the contracting and expanding brakes operating on the one drum. Many of the light weight machines use coaster types of brakes similar in design to those employed on bicycles but heavier in construction.

The brake is generally operated by a foot pedal on the right hand side of the machine the same as in automobile practice. Some cycles use a left hand pedal for the brake while others control from a hand lever attached to one of the handle bars near the grip.

- The Motor Cycle
  - Power Plant
    - Engine
    - Cooling
    - Fuel
    - Lubrication
    - Ignition
  - Transmission System
    - Clutch
    - Gear-Set
    - Starter
    - Drive
  - Running Gear
    - Frame
    - Front Forks
    - Suspension
    - Wheels and Tires
    - Brakes

CHAPTER II

THE MOTOR CYCLE ENGINE

Of the two types of engine the four-cycle is much more commonly used than is the two-cycle and it will be the four-cycle type that will be treated in detail through the first portion of this chapter. The two-cycle engine differs materially from the four-cycle type, not only in its principle of operation but also in its construction and in many of the accessories used to complete the power plant.

The elementary parts of the four-cycle engine as shown in Figure 9 include the following: First, the cylinder which is closed at one end and open at the other. Within the cylinder is a piston which is likewise closed at one end and open at the other. The closed end of the piston is toward the closed end of the cylinder. The piston is adapted to slide back and forth within the cylinder and with the force of the burning fuel acting between the closed cylinder head and the top of the piston, this latter member is forcibly driven toward the open end of the cylinder.

In order to prevent the piston from being driven all the way out of the open end of the cylinder and also in order that the reciprocating motion of the piston may be turned into a rotary motion suitable for driving the cycle, the piston is attached to one end of

a connecting rod while the other end of this rod is attached to a crank pin. The crank pin is in turn supported by the crankshaft or by the flywheels and the bearings mounted in the crankcase.

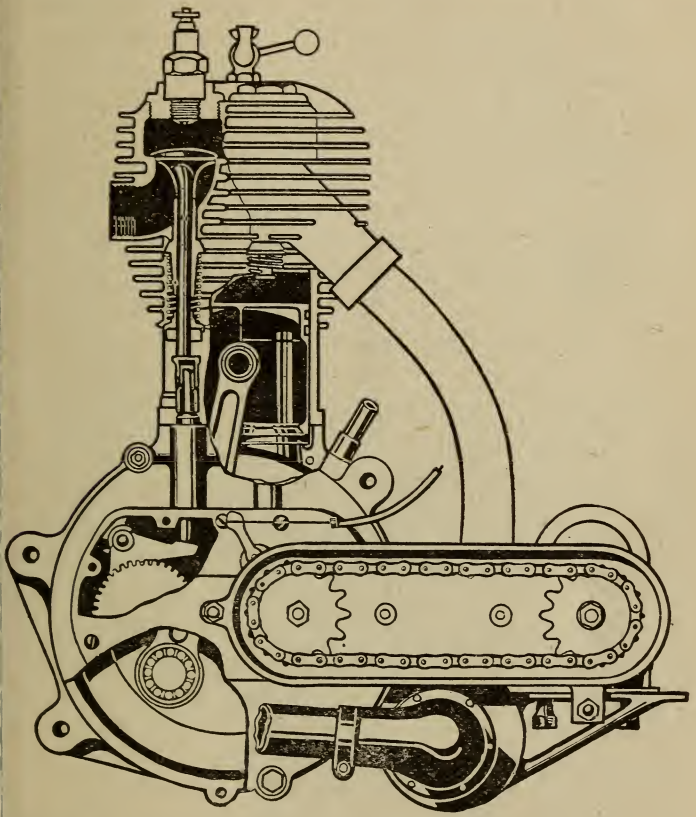

Figure 9.—Single-Cylinder Engine Cut Open to Show the Cylinder, Piston, and Connecting Rod Construction.

The length of the connecting rod is such that the piston can at no time travel all the way to the

closed end of the cylinder. At the extreme limit of piston travel there is still a certain space remaining between the top of the piston and the head of the cylinder. This is called the combustion space and within it is carried the inflammable mixture which is burned to produce power. It will be evident that means must be provided for allowing fresh gas to enter the combustion chamber and means must also be provided for allowing the spent gas to escape from this chamber. The passage of gas takes place through two valves, one of which called the inlet valve admits fresh gas while the other one, called the exhaust valve, allows escape of the burned gas.

THE FOUR-STROKE CYCLE

With the engine ready to start, the piston is at the top of its stroke by which is meant that the piston is as near to the cylinder head as it can come. The crankshaft is caused to revolve, and through the connecting rod this turning of the crankshaft draws the piston away from the cylinder head. At the same time, the inlet valve is caused to open and fresh gas is drawn into the cylinder through a pipe connected with the carburetor. Immediately following the end of the inlet stroke, when the piston has traveled as far away from the cylinder head as it can go, the inlet valve closes. This travel of the piston away from the cylinder head is called the inlet stroke. This and the remaining strokes of the cycle are shown in Figure 10.

During the inlet stroke the exhaust valve has been closed and now that the inlet valve has also closed,

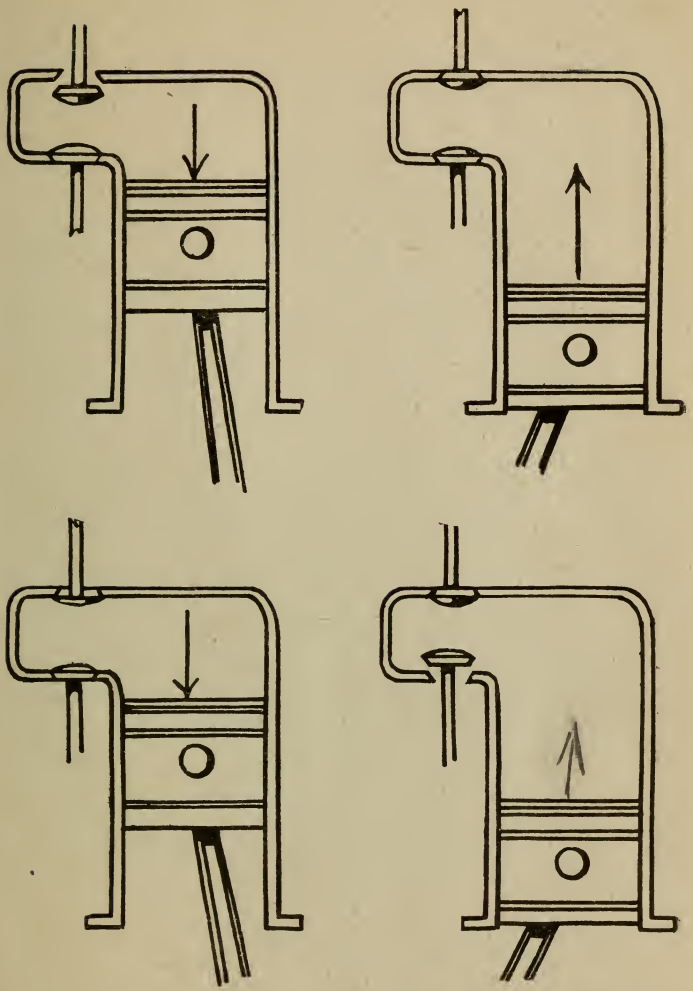

Figure 10.—Position of the Valves During the Four Strokes of the Four-Cycle Engine. Upper Left: Inlet. Upper Right: Compression. Lower Left: Power. Lower Right: Exhaust.

the fresh gas is driven ahead of the piston and up into the combustion space by continued rotation of the crank. It is necessary to thus compress the gas so that it will easily ignite and so that it will develop the required power upon burning. This second stroke during which the piston travels back toward the cylinder head is called the compression stroke.

At the end of the compression stroke, an electric spark is caused to pass through the highly compressed gas and the mixture is ignited. The heat developed in the burning mixture causes a great expansion in volume and the pressure that is generated drives the piston back toward the open end of the cylinder. This third stroke is called the power stroke and its force is utilized to turn the engine's crank pin and the flywheels so that power is delivered to the transmission system and driving parts.

At the end of the power stroke, the cylinder is filled with spent gas and in order to get rid of this gas, the exhaust valve is opened. Further rotation of the crankshaft drives the piston back toward the head of the cylinder, forcing the old gas out through the exhaust valve. This is called the exhaust stroke.

These four strokes; inlet, compression, power and exhaust; complete the cycle and leave the piston at the head of the cylinder ready to start over again. The exhaust valve is closed and the inlet valve is again ready to open. This same sequence of events takes place in each cylinder of every four-cycle engine. It is the fundamental principle of engine operation and should be thoroughly fixed in the mind, both as to the functions and actions during each stroke and as to the order in which the strokes occur one after another.

NUMBER AND ARRANGEMENT OF CYLINDERS

Motor cycle engines are made with either one, two or four cylinders. The single-cylinder engine admits

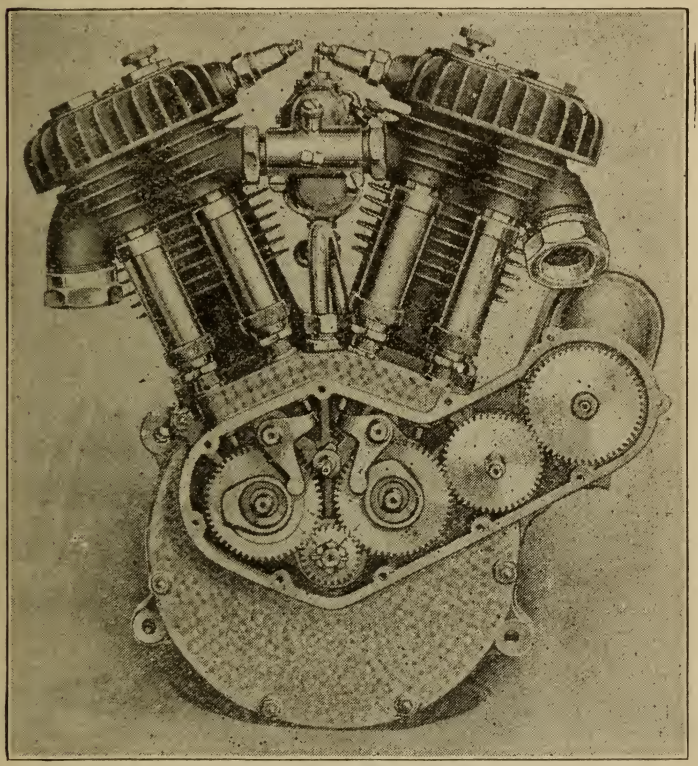

Figure 11.—Valve Operating Parts of V-type Engine (Reading Standard).

of but slight variation in the cylinder's position although even in this case it may be mounted either vertically or inclined.

Two-Cylinder Engines.—This type which is in the majority will be found in two distinctly different arrangements. According to the generally adopted method, the cylinders are set at an angle to each other forming what is known as a V engine as shown in Figure 11. The greatest angle allowed between the cylinders is ninety degrees but this great opening is seldom found. Most V engines are built with an angle of either forty-five degrees or forty-two degrees between the axes of their cylinders.

The other type of two-cylinder engine is known as the horizontal opposed. In this type the cylinder axes extend in opposite directions as shown in Figure 12. As far as motor cycles are concerned, this opposed twin is a comparatively recent development, although this was one of the earliest methods of construction used in automobile practice. Each type of engine has certain advantages and also certain disadvantages.

The V engine is especially adapted to motor cycle construction because it fits easily into the frame that is generally adopted. This engine is compact and allows the use of short passages for the gas between the carburetor and the combustion spaces. The nearly upright position of the cylinders allows very good cooling. One of the disadvantages of the V engine is found in the unequal intervals between the firing strokes of the front cylinder and the rear one, and of the firing strokes between the rear cylinder and the front one. As an example, the interval measured in degrees of the circle when applied to a V engine of forty-two degrees, will be found to amount to 402 degrees between the ignition points of the front cylinder and the real cylinder while it only amounts to

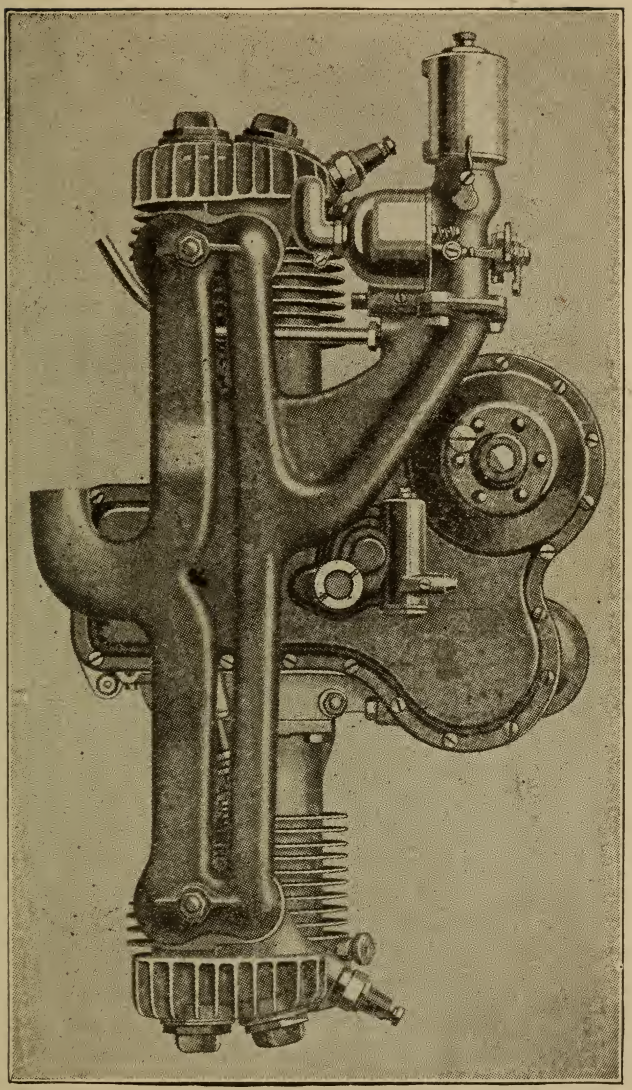

Figure 12.—Two-Cylinder Horizontally Opposed Engine (Harley-Davidson).

318 degrees between the rear cylinder and the front cylinder. At extremely low speeds this might cause some unevenness of operation, but because the motor cycle engine is of the high speed type, this apparent unevenness is not noticeable. Some difficulties are encountered in the matter of mechanical balance because of the fact that both pistons are within a few degrees of each other, moving upward at the same time and moving downward at the same time.

The opposed cylinder engine has the mechanical advantage of excellent balance because both pistons start away from the cylinder heads at the same instant and they both arrive at the other end of their strokes at the same instant. Furthermore, their velocity is the same at all times during the stroke. Thus, the reciprocating parts balance each other in the two cylinders. Unless the two-cylinder opposed engine is mounted crosswise of the motor cycle frame some difficulty may be found in cooling. That is, the rear cylinder will not always cool as readily as will the front one. The opposed twin makes the design of the inlet passages more difficult because of the comparatively great distance between the combustion spaces of the two cylinders.

Four-Cylinder Engines.—One of the more recent developments in motor cycle design has been the adoption of the four-cylinder vertical engine by a number of makers. A section through one such engine is found in Figure 13, and it will be seen that the design is almost identical with automobile practice except that the cooling is by air instead of by water. The cylinders are carried one behind the other mounted on a crankcase which supports the lengthwise crankshaft. In the particular example shown, the clutch

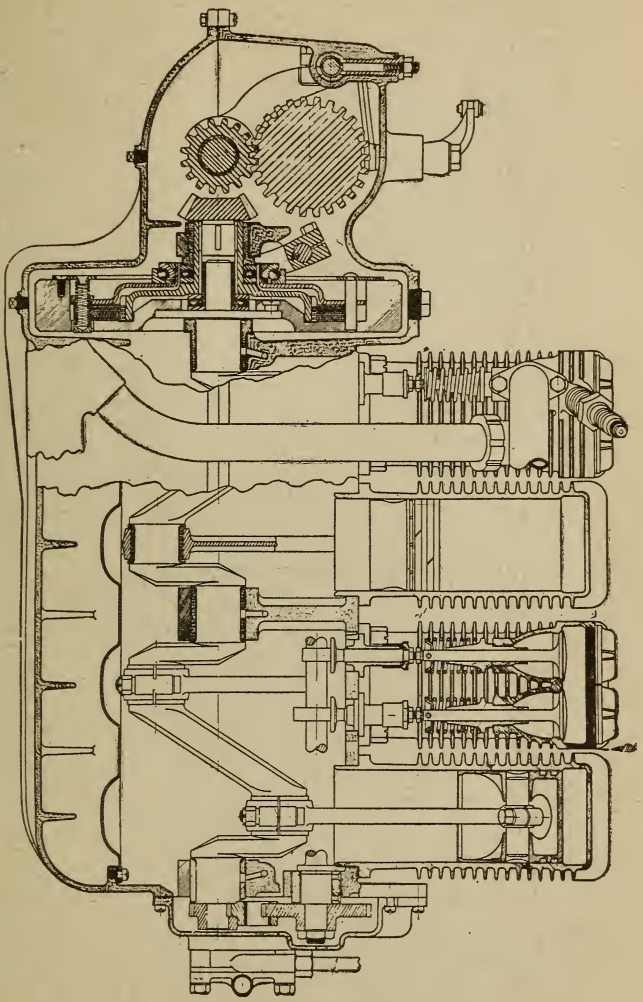

Figure 13.—Power Plant Details of Four-Cylinder Engine (Henderson).

and transmission form a unit with the engine, although this is not a necessary characteristic of four-cylinder engines any more than of other types.

Cylinder Design.—The cylinders of motor cycle engines are made from cast iron having a fine smooth grain. This material is adopted because of its comparative freedom from warping under heat and also because it readily takes on a high polish and very smooth surface for the interior of the cylinder walls.

The cylinders are formed with a flange at their lower or open end. This flange is bolted to the crankcase. In the majority of designs, the cylinder is made of one single casting but in some designs the top or head of the cylinder, that portion forming the combustion space, is made separately from the lower part. Detachable cylinder heads are adopted to facilitate the manufacturing processes of boring and grinding and as a general rule the detachable head is supposed to remain in place at practically all times during the life of the engine. This is contrary to automobile practice in which a separate cylinder head is designed to be removed for such purposes as carbon removal and valve grinding.

COOLING

The problem of keeping the temperature of the cylinder walls and of the piston at a point sufficiently low to allow for lubrication is one of the greatest importance in any internal combustion engine but it is of especial importance in the motor cycle engine because of the high speed at which these units are operated.

The maximum heat of the burning gas rises to a

point almost as high as the melting point of iron so that it is plain this heat must be almost instantly dissipated. Of course, the greater part of the heat disappears through the expansion of the gases, but there is still a very considerable remainder to be taken

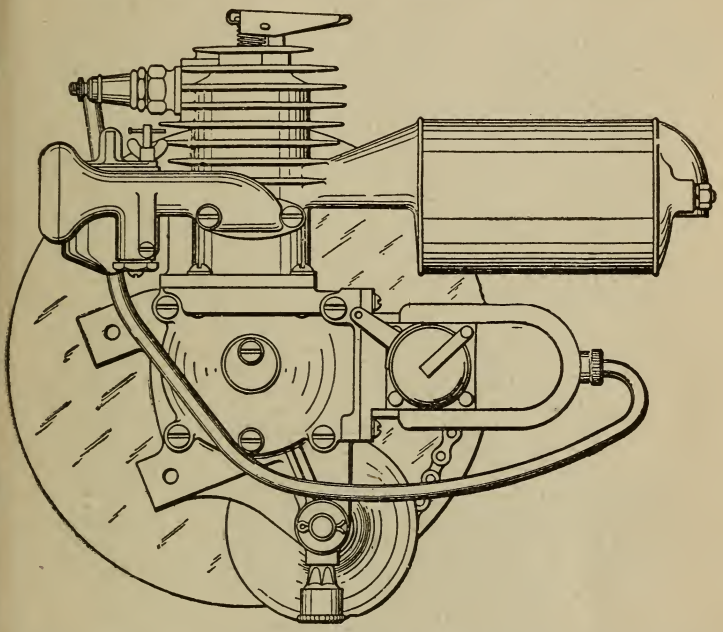

Figure 14.—Air Cooling Flanges on Single-Cylinder Engine (Cyclemotor).

away from the metal parts of the engine. It is almost a universal practice in motor cycle design to use air cooling by which the excess heat is directly carried away from the cylinder walls by air currents. This is known as direct cooling as opposed to indirect radiation through the water cooling system generally used upon the automobile.

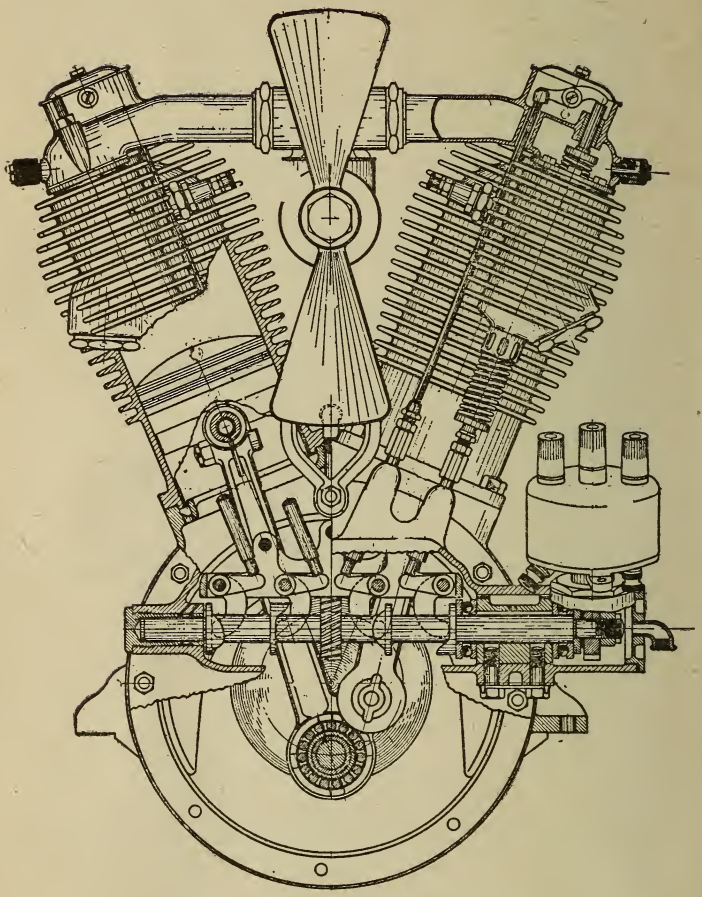

Figure 15.—Air-Cooled Engine Fitted With Fan (Spacke).

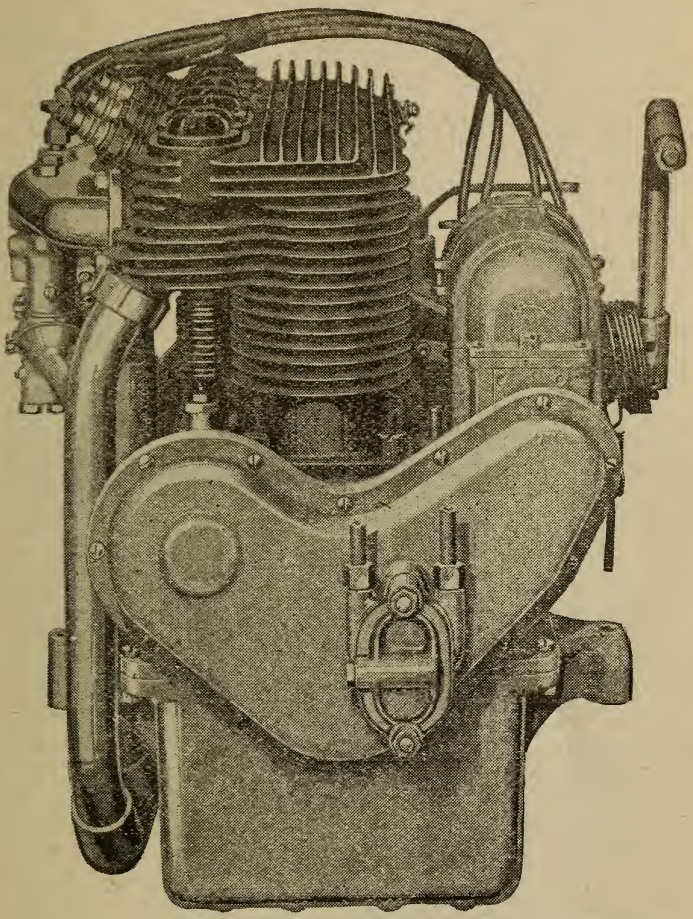

Figure 16.—Cooling Flanges on a Four-Cylinder Engine (Henderson).

Motor cycle cylinders are made with a large number of thin fins or flanges generally arranged as shown in Figure 14. The heat of combustion is absorbed by the cylinder walls and transmitted to the cooling flanges. The air that passes through and around these flanges whenever the machine is in motion, serves to rapidly reduce their temperature so that the maximum at any exposed point of the engine is held between three hundred and four hundred degrees. The water-cooled engine has its cylinder walls kept between one hundred and fifty and two hundred degrees under ordinary conditions.

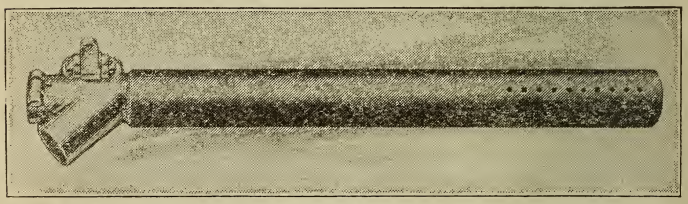

Figure 17.—Exhaust Muffler Fitted With Cut-Out (Reading Standard).

While, in a few cases, a fan has been fitted as shown in Figure 15, this practice is not often followed, the draft of air induced by motion of the motor cycle being depended upon for circulation. The cooling arrangement of a four-cylinder engine is shown in Figure 16.

Because the cooling depends on circulation of air and because this circulation depends on movement of the motor cycle, it is dangerous to run the engine for any length of time with the cycle idle. Such a practice will cause overheating and will easily result in scored cylinder walls.

PISTONS AND PISTON RINGS

The pistons of all internal combustion engines are of the same general design. They are closed at the upper or cylinder-head end and open at the lower or crankcase end. There are a great many variations in the details of design, many of which may be noted from the sectional drawings of engines in this and other chapters. The piston is made a few thousandths of an inch smaller in its outside diameter than the inside diameter of the cylinder, this being necessary to allow the piston to make a running fit. Even

Figure 18.—Piston Rings. Left: Step Joint. Right: Diagonal Joint.

though a piston might be fitted closely enough to make a gas-tight joint when first manufactured, this gas tightness would disappear as soon as some wear took place and it is therefore necessary to provide special means for retaining a tight seal between the outside of the piston and the inside of the cylinder. This seal is secured by the piston rings.

The piston rings are made from cast iron and are carried in grooves cut around the outside surface of the piston and in most cases near the top. The rings are cut through at one side as shown in Figure 18. This cutting allows them to be slipped into place over the outside of the piston and to then drop into their slots. It will be noted from several of the illustra-

tions that some makers use two rings while others use three and that some makers place all of the rings near the top of the piston while others place one of them near the lower end of the piston and the remainder near the top. A section through a typical motor cycle engine is shown in Figure 19 and from this drawing the general construction of the piston and the location of its rings may be seen.

In addition to the piston rings many designs cut a comparatively shallow groove at one or more points around the piston, these being known as oil grooves. The purpose of this groove is to collect the excess oil from the cylinder walls and to allow this excess to pass through small holes drilled into the bottom of the groove and thence through to the crank chamber. Some pistons are also drilled with rather large holes at various points around their circumference. These holes not only serve to lighten the weight of the piston but also allow a better distribution of the oil spray over the cylinder walls. Pistons having three piston rings, one oil groove and drilled holes, are shown in Figure 20.

CONNECTING ROD AND FLYWHEELS

The connecting rod, which serves as a driving unit between the piston and crankshaft or crank pins, is generally of an I section made thus for a combination of lightness and strength. In many designs the upper end of the connecting rod carries a bushing and this bushing encloses a hardened steel rod or tube which is called the piston pin. The piston pin is mounted in bosses formed in the walls of the piston. In other designs the bushings are mounted in the pis-

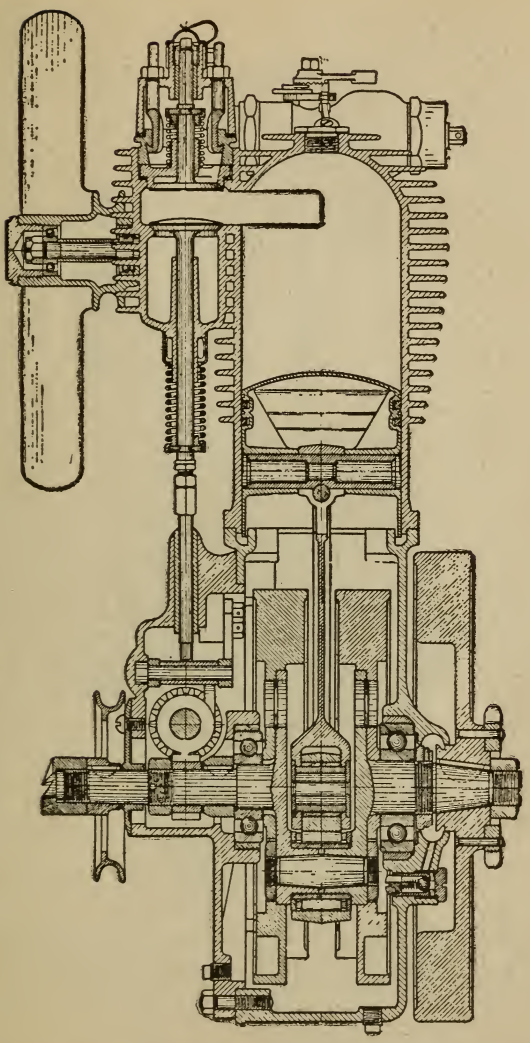

Figure 19.—Constructional Details of Engine Having Ball and Roller Bearings in the Crankcase (Spacke).

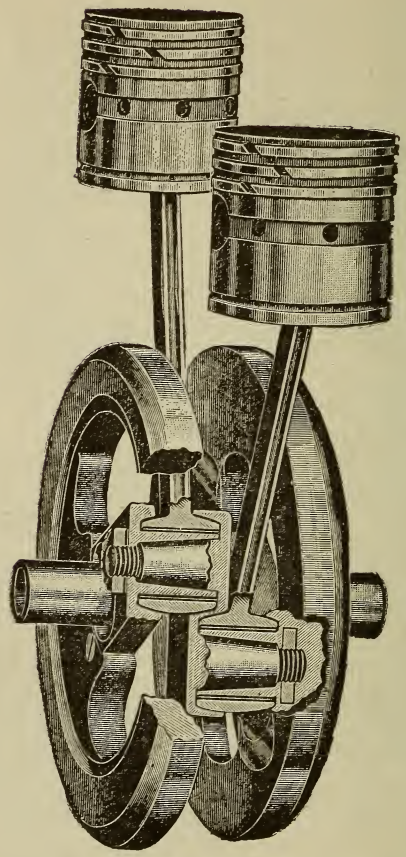

Figure 20.—Piston Construction Showing Three Rings and One Oil Groove Below. The Connecting Rods Are Mounted on Two Separate Crank Pins (Iver-Johnson).

tons and the piston pin is clamped in the connecting rod. The lower end of the connecting rod carries a bearing which in motor cycle practice may be of the plain, the roller or the ball type. This is generally called the big end bearing.

The big end bearing encloses the crank pin and the crank pin, in motor cycle practice, is generally car-

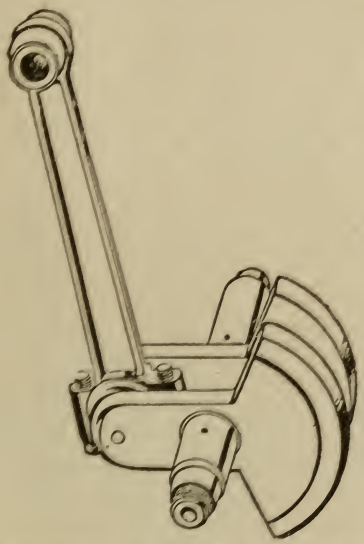

Figure 21.—Connecting Rod Attached to Counter-Balanced Crankshaft (Levis).

ried between the flywheels and supported by the flywheels. In some examples the crank pin may form a part of the crankshaft and the flywheels would then be attached to this crankshaft but the first mentioned method is the one generally used. Its application may be seen in many of the illustrations in this chapter. An example of the connecting rod attached to a

crank pin formed integral with the crankshaft is shown in Figure 21. This illustration also shows counterweights attached to the crankshaft, these counterweights serving to balance in some degree the motion of the reciprocating piston.

In single-cylinder and in twin-cylinder V type engines two flywheels are commonly employed, both being mounted inside of the crankcase. In some small single-cylinder engines, but one flywheel is used and this wheel may be carried either inside or outside of the crankcase. In opposed twins and in four-cylinder vertical engines, only a single flywheel is used and this is usually mounted outside of the crankcase at one end of the engine. The flywheels may be made from drop forgings or from cast iron. When the crank pin is attached directly to the flywheels, a part of the wheel is made heavy at a point opposite the crank pin, this heavy portion acting as a counterweight.

It will be found that in a majority of engine designs using the twin-cylinder V principle of construction, the lower or crank pin ends of both connecting rods are mounted on one and the same pin so that their angular position with reference to the flywheel rim is the same for both rods. It has been already explained that the interval between power strokes in the V engine is unequal between the two cylinders but in one form of construction this uneven interval is not present. This is the form of construction that is shown in Figure 20 and in Figure 22.

Reference to Figure 22 will make clear the effect secured with each of the two constructions. The upper drawing shows the general practice with both connecting rods attached to a single crank pin. It

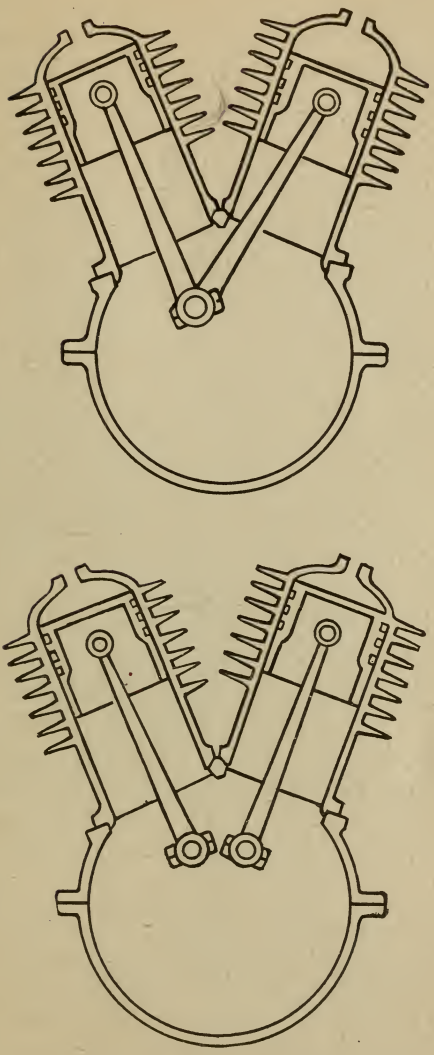

Figure 22.—Variations in Piston Position Due to the Use of One or Two Crank Pins.

will be seen that while one piston is at top dead center, the other one has either started on its down stroke or else has not finished its upward stroke. This difference of piston position accounts for the variation in the time interval between firing strokes. In the lower drawing is shown the construction which mounts each connecting rod on its own individual crank pin and it will be seen that both pistons are at their upper dead centers at the same time. This latter construction allows an even firing interval between the two cylinders.

Relieving Crankcase Pressure.— The reader undoubtedly will have noticed that the bulk of the flywheels, when these are enclosed within the crankcase, almost completely fills the space in the case. It will be realized that when the piston is on its down stroke, the air in the crankcase must be rapidly compressed because the piston displacement is large when compared with the unfilled space in the crankcase. It will also be evident that the upward stroke of the piston will produce a considerable vacuum in the crankcase. The alternating pressure and vacuum that would thus be present would tend to force oil above the piston and also to force the oil out through the crankshaft or flywheel bearings. To overcome this leakage of oil, some method is usually provided by which the pressure is relieved or by which both pressure and vacuum are relieved.

The relief valve is mechanically operated in most designs and is attached to some part of the gearing which operates the inlet and exhaust valves because, of course, the relief valve must keep time with the movement of the piston. In one design there is a rotary valve consisting of a slot cut into the shaft

carrying one of the gears and this slot registers with the opening when the piston has just started down on the firing stroke. The registering of these two openings gives the air a point of escape.

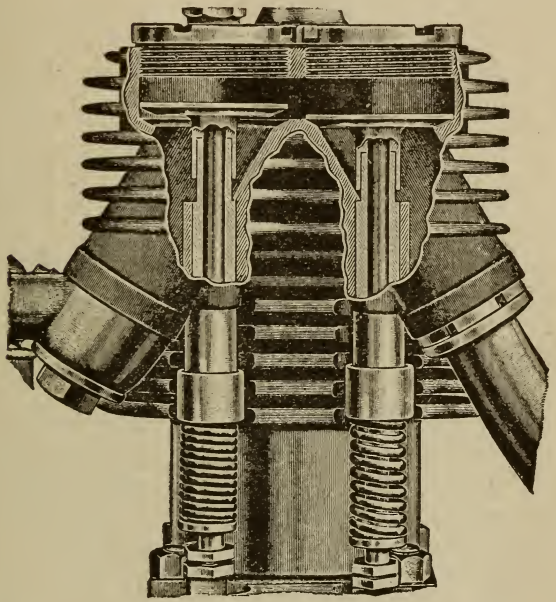

Figure 23.—Poppett Valve Action. The Left-Hand Valve Is Open and the Right-Hand One Closed (Iver-Johnson).

VALVES

The openings in the combustion chamber of the engine through which the gases pass when coming into and leaving the cylinder are closed by a poppet form of valve. This is the type of valve often defined as a lift valve. Its construction is shown in Figure 23. The various parts of the valve are defined as follows:

The head is the flat circular piece that closes the opening in the combustion chamber. The head is attached to a long rod called the valve stem. The valve stem passes through a support called the valve-stem guide. The part of the opening into the combustion space against which the edge of the head rests with the valve in place is called the valve seat, and the part of the head which rests against the seat is called the valve face.

The face and seat of the valve are formed at an angle with the main body of the head and with the valve stem. This angle is sometimes thirty degrees with the head, such construction being oftentimes used for the inlet valves. An angle of forty-five degrees is more commonly used and is generally found in the exhaust valves, even though thirty degrees may be used for the inlets in the same engine.

The valve is held on its seat by means of a coiled spring. The lower end of the valve spring is attached to the lower end of the valve stem by various methods using keys, pins and slotted washers. The upper end of the valve spring rests against or is indirectly supported from the metal of the cylinder. In Figure 23, one valve is shown open, that is, raised from its seat with its spring compressed. The other valve is shown closed, resting on its seat with its spring extended.

VALVE-LIFTER MECHANISM

The valves are closed by their springs and when it is desired to open them, the spring pressure is overcome by the action of a cam which lifts the lower end of the valve stem through a device called the valve-lifter. The valve-lifter may take any one of a great

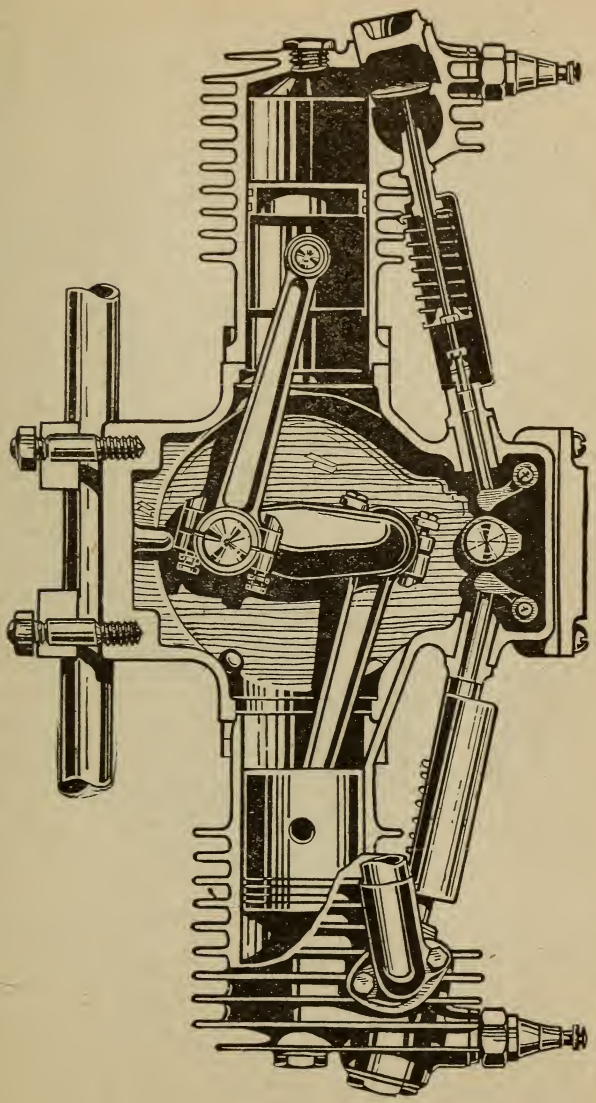

Figure 24.—Section Through Indian Two-Cylinder Opposed Engine Showing Construction of Valve Operating Parts.

variety of forms depending upon the ideas of the designer. A cam, as used in motor cycle work, may be defined as a roller having a projection at some

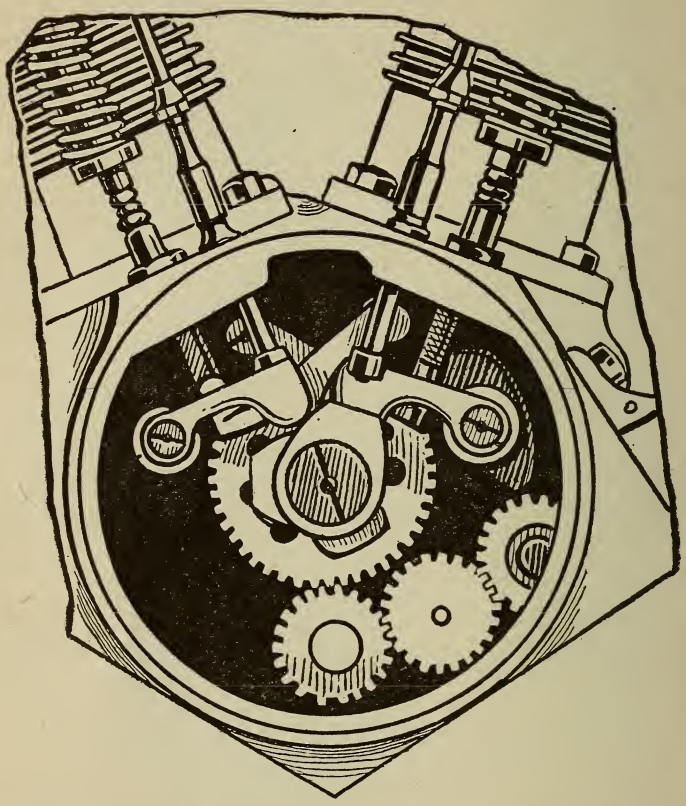

Figure 25.—Cams and Valve Lifters in V-Type Engine (Emblem).

point around its circumference or having several projections at various points.

One of the simplest forms of valve operating mech-

anism is shown in Figure 24. The valve for the left-hand cylinder is shown in its proper place and opening into the combustion chamber. The valve stem passes through its guide and the valve spring is attached to the lower end of the stem. Pressing against the valve stem is the valve-lifter proper which, in turn, is pressed against by a small pivoted arm. In the center of the illustration and directly above the crankshaft of the engine is seen the valve operating cam. In this particular case, only the exhaust valve cam is shown but the inlet cam would be directly back of it.

As the cam rotates, the valve will be allowed to remain closed until the projection of the cam comes underneath the lifter. The valve will then be opened and held open while the cam projection is passing underneath the lifter. After the cam has turned through a certain part of a revolution, the valve will be closed by its spring. The length of time during which the valve remains open is determined by the shape and size of the cam projection. The cam is positively driven by means of gearing or chains. More consideration will be given to this cam drive a little farther along. Details of the lifter device used with one V type engine are shown in Figure 25.

VALVE LOCATION

An examination of many of the engine illustrations in this and other chapters will show that both the inlet and exhaust valves are often mounted in a pocket-like projection formed at one side of the combustion chamber. This is known as the side-by-side location for valves. Other engines, for example, the

type shown in Figure 26, mount only the exhaust valve in the lower part of the combustion chamber pocket while the inlet valve is carried directly above the exhaust valve and in the top of the same pocket. In this latter design the inlet valve is operated by

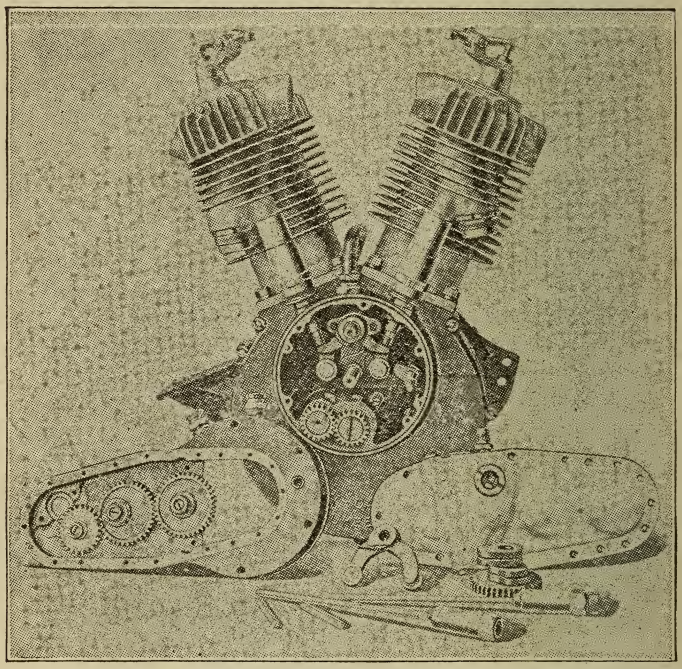

Figure 26.—Valve Mechanism of Harley-Davidson V-Type Engine.

means of a valve-lifter which presses against a push rod. The push rod presses against one end of a valve rocker lever and the other end of this valve rocker lever presses down upon the end of the inlet valve stem and thus opens the valve. In the side-by-side

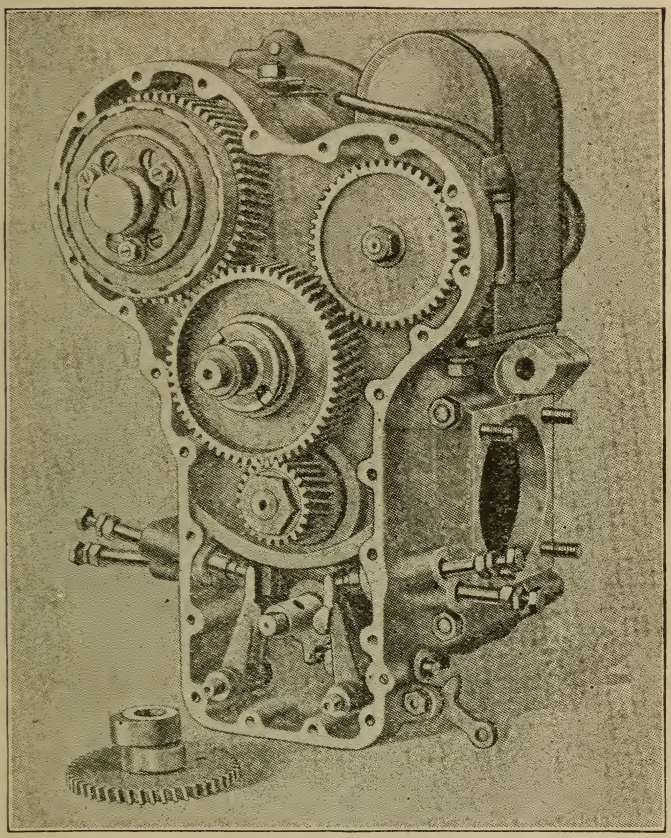

Figure 27.—Gear and Cam Mounting of Harley-Davidson Two-Cylinder Opposed Engine. The Cams With Their Large Driving Gear Are Seen Removed in the Lower Part of the Illustration.

type of engine, both valves are operated directly from their lifters with the use of the push rod and rocker.

There is always a great deal of discussion as to the relative merits of these two types of design. Each one has certain undoubted advantages in its favor, but, like almost everything else in mechanics, each has certain points against it. In actual practice, either type of design when well built, gives excellent results and the choice between the two rests with the ideas of the designer as to the relative importance of the various advantages and disadvantages. Motor cycle engines have also been built with both of the valves mounted in the head but at the present time this practice is very much in the minority, the side-by-side or side-and-head locations being used by almost all of the manufacturers.

VALVE TIMING

Before describing the exact methods of timing the opening and closing of the valves in relation to the travel of the piston, it will be necessary to explain a few additional details about two of the strokes of the engine. The elementary principles governing the strokes have already been briefly treated in an earlier portion of this chapter.

Inlet Stroke.—The inlet stroke commences at or near the upper dead center position of the piston. With the inlet valve open and the piston moving downward on the inlet stroke, the charge of fresh gas is drawn from the carburetor. When the piston reaches the bottom of its stroke the fresh gas is entering the cylinder at a great rate of speed and this stream of gas has a considerable momentum. Even

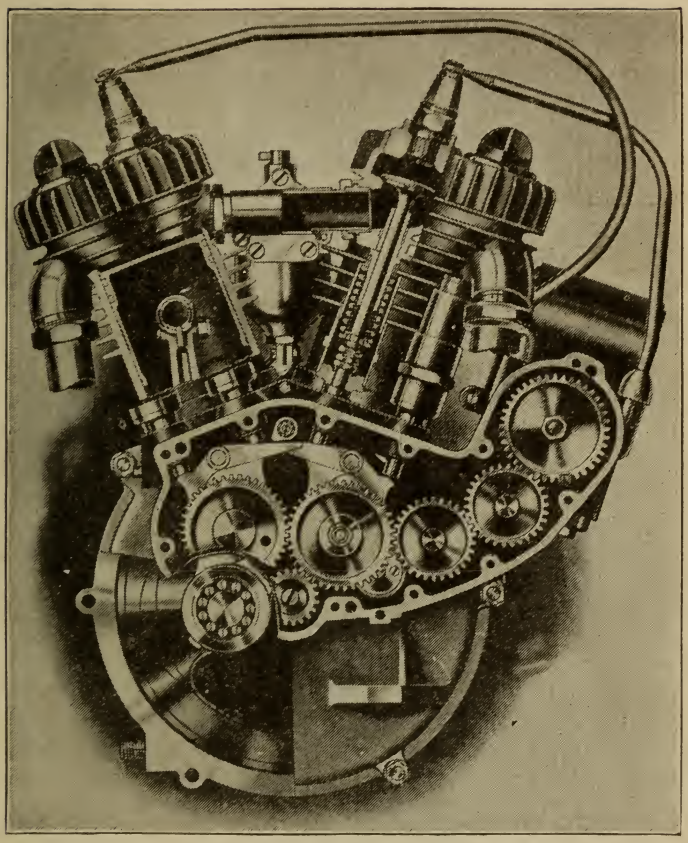

Figure 28.—Valve Operating and Ignition Driving Gears in the Indian V-Type Engine.

with the piston at the bottom of its stroke, the cylinder has not been completely filled with gas because a partial vacuum has been produced by the rapid motion of the piston. The inrushing gas is tending to destroy this vacuum but if the inlet valve were to close as soon as the piston reached bottom center, the gas stream would be shut off and the cylinder would remain only partly filled with fresh gas. In actual practice the inlet valve does not close at lower dead center but is allowed to remain open until the piston has started upon the next upward stroke (compression stroke). Even with the piston traveling on the upstroke the gas continues to enter the cylinder because of this momentum.

Exhaust Stroke.—The maximum pressure of the burning gas is supposed to occur with the piston at its top center following the compression stroke. This pressure rises to a value of several hundred pounds to the square inch. As the piston passes down on the power stroke, the pressure becomes less and less but even with the piston at the bottom of the power stroke the pressure is still very high and if this high pressure were allowed to remain when the piston starts back on the exhaust stroke, it would mean that the engine would have to overcome so much back pressure that there would be a very considerable reduction in the power output. In order to reduce this back pressure as much as possible the exhaust valve is opened before the piston reaches the bottom of the power stroke so that the gas may start to escape. The exhaust valve remains open through and to the end of the down stroke, all through the next upward stroke (exhaust) and in a great many engines the exhaust valve remains open slightly after the upper

dead center following the exhaust stroke. This may allow the two valves to be open at the same time.

It is not the general practice to allow the exhaust valve and the inlet valve to be open at the same time because the burning gas might possibly be forced back into the inlet pipe. Therefore, as the exhaust valve stays open slightly after the upper dead center following the exhaust stroke, and if the valves should not be open at the same time, it requires that the opening of the inlet valve be delayed until after this upper dead center. This delayed opening of the inlet valve has no great effect on the volume or quantity of fresh gas drawn into the cylinder because even were the inlet valve to remain closed until the piston had descended to a considerable distance, the vacuum that would thus be formed would simply serve to increase the speed of the incoming gas when the valve finally opened.

Timing Gears.—In order to fix in the mind the relation between valve action and the position of the piston, the four strokes of the engine should be considered. The first stroke is the inlet and the piston travels downward. The second is the compression with the piston traveling upward. This second stroke completes the first revolution of the crankshaft. The third stroke is the power or firing stroke with the piston moving downward and the fourth is the exhaust stroke with the piston moving upward. The third and fourth strokes complete the second revolution of the crankshaft during the complete cycle. Thus, for one cycle there are two revolutions of the crankshaft and four strokes of the piston. During the complete cycle of two revolutions the inlet valve opens once and the exhaust valve likewise opens once. Therefore,

in order to operate the valves at the correct time their cams must run at one-half the speed of the crankshaft so that each valve may be made to open during each second revolution. The connection between the crankshaft and the camshaft is generally made by gears, as in Figure 28, and when it is thus made, the gear on the crankshaft has just one-half the number of teeth as has the gear on the camshaft. This relation of two to one allows the camshaft to run at one-half the speed of the crankshaft. The meshing of the gears with each other determines the exact point during the strokes at which the valves open and close.

Timing by Degrees or Inches.—There are two methods by which the position of the piston in its stroke may be described. One method consists of telling what fraction of an inch the piston has traveled from top center on the down stroke, or else of giving the fraction of an inch that the piston lacks of reaching the lower end of its stroke. The topmost position of the piston is called top center and the lowermost position is called bottom center. The exact position of the piston may be given as before or after top center or else before or after bottom center.

The second method of telling the position of the piston is according to the degrees of a circle, the circle being considered as a revolution of the crankshaft and generally being marked or measured on the rim of the flywheel. A complete circle contains 360 degrees, and 360 degrees would therefore equal one revolution. A half circle, or 180 degrees, would equal one stroke. If the piston were half way down in its stroke it would have traveled 90 degrees and its position would then be given either as 90 degrees after top center or 90 degrees before bottom center.

Valve timing positions are generally given in degrees of the circle with reference either to top or bottom center.

Inlet Valve Timing.—It has been stated that the inlet valve opens after the exhaust valve closes and

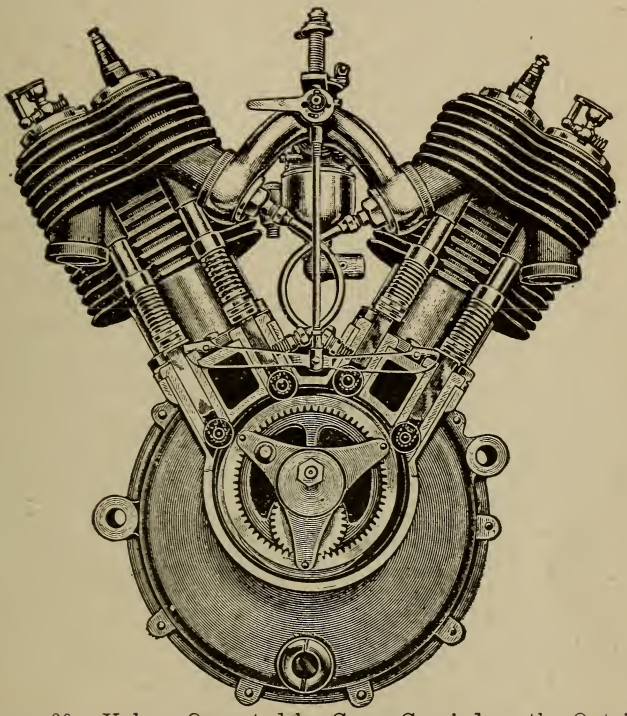

Figure 29.—Valves Operated by Cams Carried on the Outside of an Internally Toothed Timing Gear (Iver-Johnson).

this is true in most cases but there are many engines built in which the exhaust closing and inlet opening overlap one another. In this case the inlet valve opens before the exhaust valve has closed. The exact time

of opening the inlet valve really depends on the closing of the exhaust valve more than on any other one factor.

It has been shown that the inlet valve should remain open after bottom center in order to allow a full charge of gas to enter the cylinder. The point of closing the inlet varies between thirty and sixty degrees after bottom center following the inlet stroke, the exact point of closing depending on factors such as the engine speed and the resistance to gas flow encountered in the gas passages.

Exhaust Valve Timing.—The exhaust valve closes anywhere from top dead center following the exhaust stroke up to as much as thirty degrees after top dead center. This closing point is dependent upon engine speed and various other factors. The higher the speed of the engine and the greater the difficulty of getting rid of the exhaust gas, the later will the exhaust valve close.

The exhaust valve is opened anywhere from thirty to sixty degrees before bottom center. This, like the other valve-timing points, depends on the general design and speed of the engine. The earlier the exhaust valve opens, the less will be the back pressure at the end of the exhaust stroke but too early opening would allow too much loss of the expanding gas and the net result would be a reduction in power.

COMPRESSION RELEASE

Motor cycle engines are put into motion either by means of a starting crank which is foot operated or by wheeling or pedaling the cycle. Because of the high compression that is used in a great many of these

engines, the cranking operation required in starting may be found quite difficult. In order to make these engines easy to crank, the compression is often relieved to a certain extent by means of lifting the valves part way from their seat or by providing a special relief valve. This device is called either the compression release or the valve lifter, the latter term being incorrect.

In one typical design, the construction of the compression release is as follows: Between the two inlet valve rockers is a short shaft having a toothed segment near one end. This segment meshes with teeth cut on the circumference of a cam plate; known as the exhaust valve relief cam. On the surface of the plate are formed cams which lift the exhaust valves through the rockers and valve-lifter when the plate is moved to a certain position.

HORSEPOWER

The actual power developed by any internal combustion engine can be accurately determined only by running tests. The results of such tests are generally plotted in the form of curves and are made available by a great many engine and motor cycle manufacturers.

The nominal horsepower is often calculated by means of some one or another of many different formulas. The most generally used horsepower formula is that which has been adopted by the Society of Automotive Engineers (S. A. E.). This formula was derived from the older one for horsepower in which were considered the mean effective pressure, the length of the stroke, the area of the piston head and the num-

ber of cylinders in the engine. In using this older formula it was generally difficult to arrive at the mean effective pressure without having indicator card data. In the S. A. E. formula, this factor is eliminated by assuming an average for this pressure. The factor of the length of stroke is also eliminated by assuming that the engine is running at a speed which causes the piston to travel a thousand feet per minute.

The formula for S. A. E. horsepower of a four-cycle engine is as follows:

$$H\ P = \frac{D^2N}{2\frac{1}{2}}$$

In this formula, *D* stands for the diameter of the piston, which is generally called the bore of the engine or of the cylinder, and *N* stands for the number of cylinders. In arriving at the horsepower, the number representing the bore is squared; that is, multiplied by itself, and this product is multiplied by the number of cylinders. The last product thus arrived at is divided by 2½ and the quotient gives the horsepower.

It is often stated that this formula does not take into account the length of stroke and that therefore it is inaccurate. This conclusion is incorrect because the S. A. E. formula assumes that the engine will be running at a piston speed of a thousand feet per minute. In order for an engine with a short stroke to reach this speed, its number of revolutions per minute will have to be a great deal higher than the number of revolutions per minute of an engine having a longer stroke. For example: A thousand feet per minute equals twelve thousand inches per minute. If the stroke is three inches, one revolution or two strokes will make six inches travel, and twelve thousand

divided by six gives two thousand revolutions per minute as the speed at which this engine will develop its S. A. E. horsepower. If the stroke were only one-half as long, then the engine would have to go twice as fast to develop the same power.

Displacement.—Engines are more easily compared according to their piston displacement than according to their S. A. E. horsepower because the piston displacement takes direct account of both the bore and the stroke but leaves speed out of consideration.

The piston displacement is the volume of gas displaced when the piston moves from one end of its stroke all the way to the other end. This volume is calculated by multiplying the area of the piston head by the length of the stroke. The following table gives the piston head areas of motor cycle engines. By multiplying the proper area by the length of the stroke, the displacement may be determined.

AREAS OF PISTON HEADS

Bore Diameter	Area in Square Inches	Bore Diameter	Area in Square Inches	Bore Diameter	Area in Square Inches
$1\frac{1}{2}$	1.767	$2\frac{1}{4}$	3.976	3	7.069
$1\frac{9}{16}$	1.917	$2\frac{5}{16}$	4.200	$3\frac{1}{16}$	7.366
$1\frac{5}{8}$	2.074	$2\frac{3}{8}$	4.430	$3\frac{1}{8}$	7.670
$1\frac{11}{16}$	2.237	$2\frac{7}{16}$	4.666	$3\frac{3}{16}$	7.980
$1\frac{3}{4}$	2.405	$2\frac{1}{2}$	4.909	$3\frac{1}{4}$	8.296
$1\frac{13}{16}$	2.580	$2\frac{9}{16}$	5.157	$3\frac{5}{16}$	8.618
$1\frac{7}{8}$	2.761	$2\frac{5}{8}$	5.412	$3\frac{3}{8}$	8.946
$1\frac{15}{16}$	2.948	$2\frac{11}{16}$	5.673	$3\frac{7}{16}$	9.281
2	3.142	$2\frac{3}{4}$	5.940	$3\frac{1}{2}$	9.621
$2\frac{1}{16}$	3.341	$2\frac{13}{16}$	6.213		
$2\frac{1}{8}$	3.547	$2\frac{7}{8}$	6.492		
$2\frac{3}{16}$	3.758	$2\frac{15}{16}$	6.777		

TWO-CYCLE ENGINES

With the engines that have been described in the preceding pages, four strokes and two revolutions are required in order to complete the cycle which is necessary for the production of one power stroke. That type is called the four-stroke cycle or, more commonly, the four-cycle engine.

There is another type of internal combustion engine properly called the two-stroke cycle but whose name is generally abbreviated with the words, two-cycle. This type of engine is in quite common use for light weight machines both as a built-in part of the motor cycle and as an attached power plant for a bicycle.

In the two-cycle engine there are the four functions of inlet, compression, power, and exhaust, the same as in the four-cycle type, but all of the functions for one cycle are completed with two strokes of the crank shaft. This is made possible by utilizing a gas tight crankcase and performing a part of the compression in this crankcase.

The most generally used type of two-cycle engine is the three-port design, and the action of a typical power plant of this kind may be understood by reference to Figures 30 to 34. The following explanation is adapted from the description given by the Cleveland Motor Cycle Manufacturing Co., and applies to their engine, but is equally descriptive of almost all two-cycle designs such as used in motor cycle practice.

Referring to Figure 30, the parts are named as follows: *A* is the cylinder, *B* the piston, *C* the connecting rod, *D* the piston pin, *E* the crank pin, *F* the flywheel, and *G* the air tight crankcase. At *H* is the inlet port or opening through which gas is admitted

to the engine. The exhaust port *K*, through which the burned gas escapes, is directly above it. By-pass *L* is a passage which connects the crankcase with the cylinder through the transfer port *M*. *R* is the spark plug between the points of which the spark for ignit-

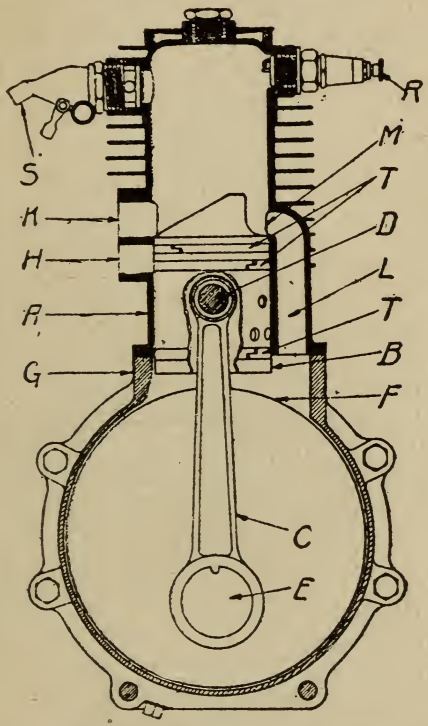

Figure 30.—The Parts of a Two-Cycle Engine (Cleveland).

ing the gas takes place, and *S* is the compression release valve.

Starting with the piston at the bottom of the cylinder as shown by Figure 30, assume that the flywheel

is being slowly turned, moving always in the same direction. As the flywheel turns, the piston, pushed up into the cylinder by the connecting rod, acts as an

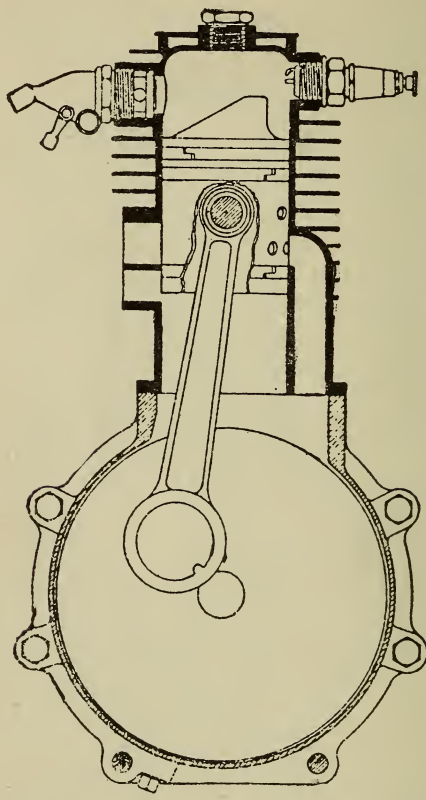

Figure 31.—Two-Cycle Engine With Piston Beginning to Uncover the Inlet Port.

air pump. This creates a partial vacuum in the crankcase which, as previously mentioned, is air tight. As the piston moves up to the position shown in Figure

31, its lower edge begins to uncover the inlet port, leaving an opening through which the gas passes as it is drawn in by the vacuum in the crankcase.

By the time the piston reaches the top of the cylin-

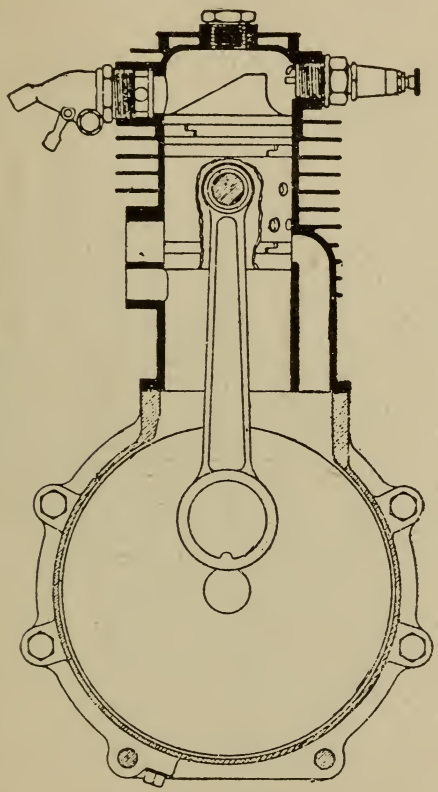

Figure 32.—Two-Cycle Engine With Inlet Port Fully Open.

der as in Figure 32 the inlet port is entirely uncovered and the engine has taken in a full charge of gas. Continued movement of the flywheel causes the con-

necting rod to pull the piston back toward the lower end of the cylinder, closing the inlet port and preventing the escape of the gas which has just been drawn into the crankcase. Further downward travel

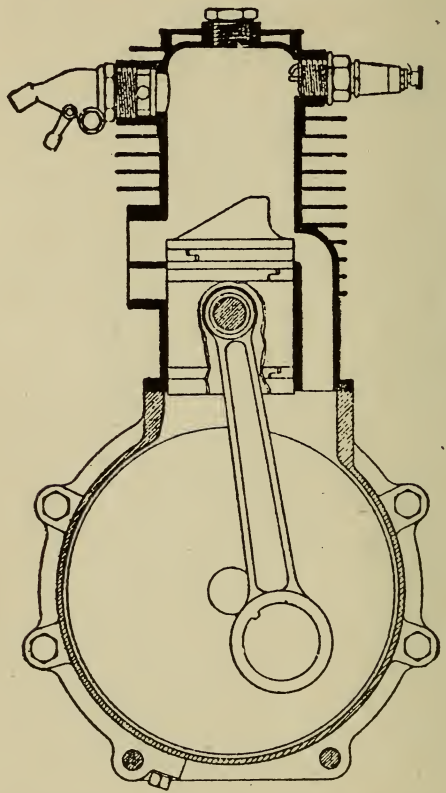

Figure 33.—Two-Cycle Engine With Piston Beginning to Uncover the Transfer Port.

of the piston compresses this gas, until in the position shown in Figure 33, the piston's upper edge begins to uncover the transfer port, allowing the compressed

gas to pass from the crankcase through the by-pass into the cylinder.

When the piston reaches the bottom of the cylinder and is back in the position shown by Figure 30, the transfer port is wide open and the full charge of gas has passed from the crankcase to the cylinder.

It will be noted that at this time the exhaust port is also wide open, and it might be expected that the incoming gas would pass directly over the piston and out of the exhaust port without doing any useful work. However, this is avoided by means of a projection or baffle plate on top of the piston, the object of which is to deflect the incoming gas toward the top of the cylinder and away from the open exhaust port. The position of this baffle with reference to the exhaust port is of great importance in the engine's operation.

The piston now starts once more on its upward travel, closing the exhaust and transfer ports and again compressing the gas which is now in the cylinder instead of in the crankcase. In the meantime another vacuum is being created in the crankcase and the inlet port opened to admit another charge of gas, exactly as was done during the first upward stroke. At the instant when the second upward stroke is completed and the piston is once more in the position shown by Figure 32, the compressed gas above it is ignited by a spark at the spark plug, driving the piston down on its power stroke and at the same time compressing the fresh charge in the crankcase. Nearing the end of this stroke the top of the piston uncovers the exhaust port as in Figure 34 and allows the burned gas to escape through the muffler and outlet pipe.

Immediately after the opening of the exhaust port

the transfer port is again opened to admit fresh gas as in Figure 33, thus completing the cycle of operations which, after the motor is started, is repeated at

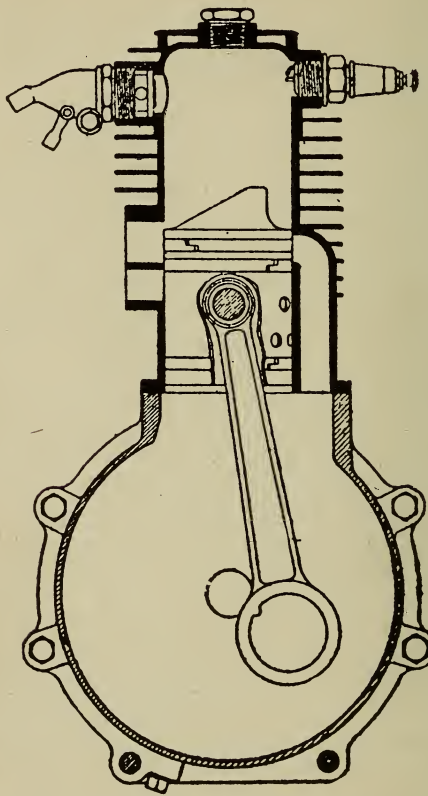

Figure 34.—Two-Cycle Engine With Piston Beginning to Uncover Exhaust Port.

every revolution of the flywheel or "two strokes" of the piston. The complete Cleveland power plant is shown in Figure 35.

In some two-cycle designs, part of the gas which passes from the crankcase to the cylinder through the by-pass travels through openings cut through the wall of the piston, this being shown by the arrows in Fig-

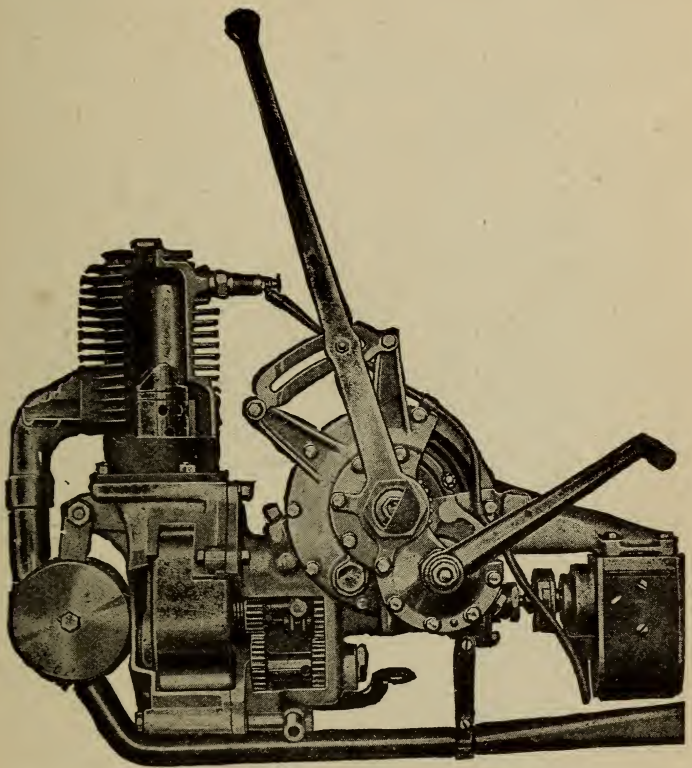

Figure 35.—Power Plant Using Single-Cylinder Two-Cycle Engine (Cleveland).

ure 36. In small two-cycle engines it is necessary to make the air space of the crank chamber quite limited in volume in order to produce sufficient compres-

sion pressure at this point. The construction of an engine having closely fitted parts in the crankcase is shown in Figure 37.

Two-Cycle Oiling.—In the usual type of four-cycle engine the lubricating oil is carried to the crankcase

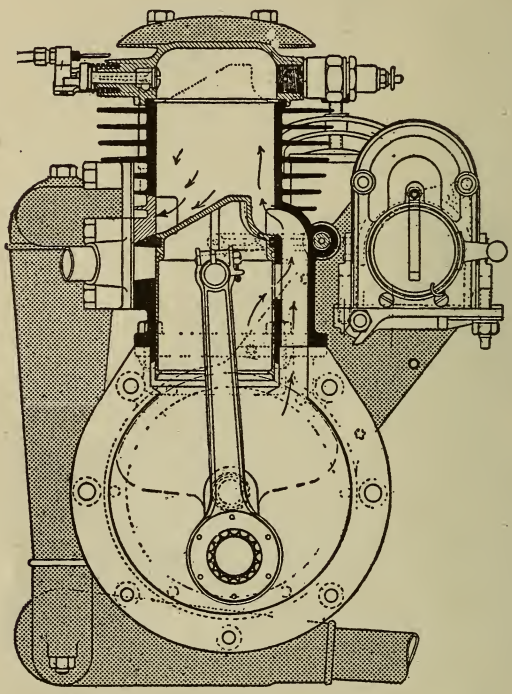

Figure 36.—Flow of Gases Through Two-Cycle Engine Having Port Hole in the Piston (Precision).

and this oil is splashed about by the connecting rod so that the bearings and the cylinder walls are lubricated. This scheme of oiling would not be practical in a two-cycle engine because such a quantity of the

lubricant mixed with the crankcase gas would have a detrimental effect on the mixture. Two-cycle engines are lubricated by mixing oil with the fuel in the fuel tank in such proportions that there are ten to sixteen parts of fuel to one part of oil. The manufacturers' instruction books specify the proportions which should be used and they also specify the grade or kind of oil which should be bought.

It is quite possible that peculiar conditions of service will call for a variation from the oil proportion recommended. Hard, long or fast driving will require a greater amount of oil just as it would in a four-cycle engine and it may be best to increase the quantity. However, an excess of oil will produce greater carbon deposits and there may be some trouble expected with the spark plug and with clogging of the exhaust lines.

It is never advisable to pour oil directly into the crankcase under ordinary service conditions. Neither is it well to attach drip oilers or force pumps. If the proportion of oil in the fuel is correct, the two-cycle engine will be properly lubricated without any additional attention.

If a two-cycle machine has remained idle for some length of time a little additional oil may be introduced into the engine by slowly pouring the oil into the air inlet of the carburetor just after the engine has been started. After the excess of smoke has disappeared the machine may be driven as usual.

A side and a front section through a two-cycle engine are shown in Figures 38 and 39. In these illustrations may be seen some of the details of a practical design.

It is necessary that the oil be thoroughly mixed with the fuel in the main supply tank, for should there

be any separation of the two liquids it is quite probable that the carburetor will become clogged. It is always best to mix the oil and the fuel in a separate can before pouring the mixture into the tank. Shake the mixture thoroughly and make sure that no oil

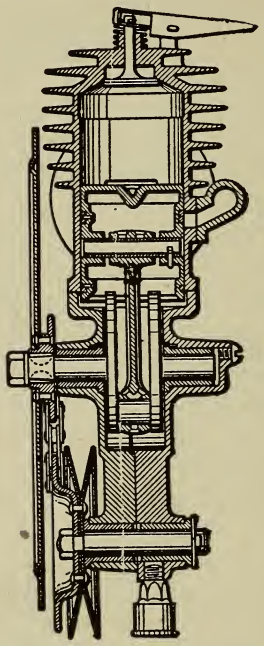

Figure 37.—Close Fitting of Parts in a Two-Cycle Crankcase.

remains unmixed in the bottom of the can. Should it be impossible to do this work in a separate receptacle, one-half of the fuel may be poured into the supply tank and oil then added. The liquids should be well shaken in the tank and the balance of the fuel finally added. The gasoline and oil will not separate after they are once properly mixed.

Two-Cycle Horsepower.—For a given bore and stroke, the two-cycle engine will develop more power than will the four-cycle type. This is because the two-

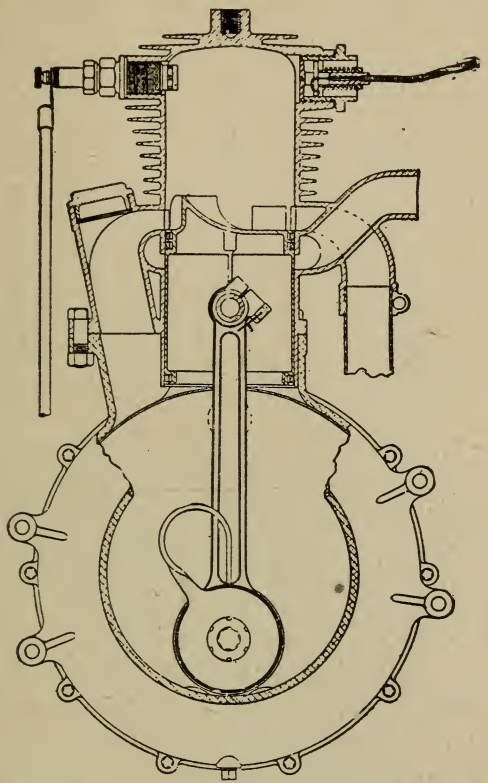

Figure 38.—Piston and Port Construction of Two-Cycle Engine (Schickel).

cycle has twice as many power strokes in a given number of revolutions as the four-cycle.

From the above it might be assumed that a two-cycle engine of a given size would develop twice the

power of the corresponding four-cycle, but this is not the case, because the two-cycle is less efficient and does not use the fuel to such good advantage as does the four-cycle. The compression pressure cannot be carried as high in a two-cycle engine, the burned gas is not so thoroughly ejected from the cylinder, and there is a certain loss of fresh gas through the exhaust port.

The generally accepted ratio between the two types of engine is that the two-cycle develops 1.65 times the power that is developed by a four-cycle of the same size. In order to arrive at the power of the two-cycle engine by means of a formula the following is used: The cylinder bore or diameter is squared; that is, multiplied by itself; the result is multiplied by the number of cylinders and the second result is divided by 1.515, when the quotient will give the horsepower of the engine.

Two-Cycle Troubles.—There are some points about two-cycle engines which require special attention in order to secure satisfactory operation. One of the most necessary cautions to be observed is in keeping the spark plugs well cleaned, for they have a tendency to foul to a greater extent in the two-cycle engine than in a four-cycle type.

The importance of maintaining a correct mixture of lubricating oil with the fuel has already been explained, and if this point is not attended to trouble of various kinds will surely result. If the proportions are incorrect or if the liquids are not well mixed the result may be hard starting, lack of power, overheating, or knocking.

A too rich mixture will cause the two-cycle engine to four-cycle; that is, to fire only on each second revolution. If one of these engines fires regularly, but

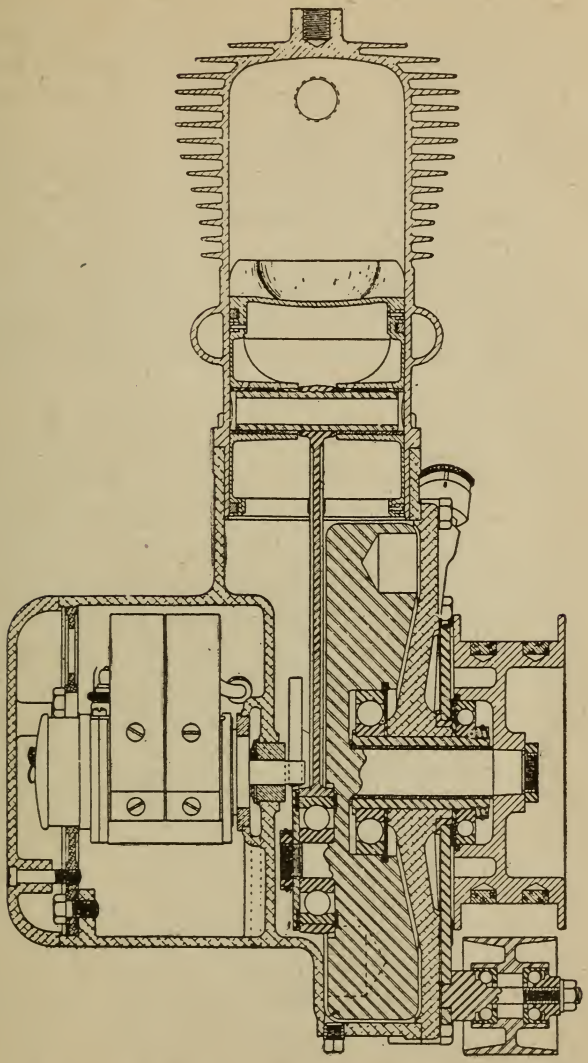

Figure 39.—End Section Shewing Crankcase Construction of Schickel Engine.

less frequently than usual, and shows a tendency to emit considerable smoke even after warmed up it generally indicates that the mixture is too rich in fuel and it should be made leaner.

Carbon deposits do not affect the two-cycle engine as harmfully as they do the four-cycle because of the absence of poppet valves over which the exhaust gases pass. However, an excessive collection of carbon in the exhaust ports or in the muffler will cause a decided loss of power, and such deposits should be removed once in each two to five thousand miles of travel.

CHAPTER III

ENGINE OILING

A great deal may be said about scientific or semi-scientific methods of determining the value and suitability of an oil for a certain engine. Farther along in this chapter these methods will be described; but, after all, there is one rule which, if followed, will obviate the necessity for such tests, and this rule is:

Buy good oil, made and recommended by a well known refiner, and be sure that you get this kind of oil when you buy.

Practically all oil makers publish charts of recommendations, and in one of these charts you will find the name and model of your motor cycle together with the grade of lubricant suitable for each season.

It pays to buy good oil, because money saved here would be spent many times over on worn out engines. Good oil will wear itself out in lubricating, but with poor oil the wear will be on the engine itself.

Whenever possible oil should be bought in original labeled cans or barrels; or, if this is not possible, be sure of the origin of bulk oil that is bought openly by the measure. All grades of oils are produced by all kinds of makers and are sold through many channels. Some are good and some are anything but good; therefore, it pays to be careful and to insist on knowing your oil and its origin.

Requirements.—An engine oil must first of all pro-

vide a film between the surfaces of moving parts, such as bearings and pistons. This film must keep these surfaces separated so that the wear will be of the oil and not of the parts. The oil is also depended upon to form a seal between the piston and the walls of the cylinder so that fresh, burning and spent gases may be kept above the pistons.

In order to do these things satisfactorily the engine oil must spread easily over the surfaces, it must flow freely to the parts and cling tenaciously to them. Last of all, when the oil does get above the pistons and exposed to the inflamed gases it must burn clean and without leaving an excess of soot or carbon. A certain oil may do all of these things in one engine, and yet fail in another because the suitability of the oil depends on the age and condition of the mechanism, on the type of construction and on the kind of oiling system that is used in the engine.

The qualities of an oil which are generally spoken of are shown in the following list, arranged in the order of their importance:

(1) Viscosity, "thickness" or "body."
(2) Flash point.
(3) Freedom from acids and alkalies.
(4) Specific gravity, "Baume test."
(5) Cold test.
(6) Carbon residue.
(7) Fire point.
(8) Color.

Viscosity.—This quality determines the ability of the oil to flow freely at various temperatures and to a certain extent indicates its ability to form a satisfactory film for the bearings and an efficient piston

seal. The viscosity of an oil varies greatly with its temperature, becoming less as the heat increases and generally being given, for purposes of comparison, at 100° F., also in some cases at 200° to 212° F. and at 60° to 70° F. The viscosity is given as the number of seconds required for a given quantity of oil to flow through a certain size opening at the temperature named.

Flash Point.—This is the temperature at which the oil gives off an inflammable vapor which, upon presentation of a flame, will ignite or "flash," but which will not continue to burn. An oil having a high flash point does not vaporize in the crankcase and escape as quickly as one with a low flash.

Freedom from Acids and Alkalies.—An engine oil should be "neutral" chemically; that is, have no remaining traces of either acids or alkalies which were used during the processes of refining, cleaning and bleaching.

When an acid or an alkali is heated, as it would be in the engine, it attacks the surfaces of shafts and bearings and rapidly pits and corrodes the valve faces and seats.

The neutrality of any oil or grease may be tested by securing a supply of both red and blue litmus paper strips from a drug store. Immerse the paper in the oil being tested and if acid is present the blue paper will turn red, while if the oil contains free alkali the red paper will turn blue.

Specific Gravity.—This measures the weight of a given volume of the oil when compared with the weight of an equal volume of water. It is measured in degrees on the "Baume" hydrometer scale and is usually taken at 60° F. The gravity of an oil has, in general, little

to do with its lubricating qualities. Pennsylvania and Eastern oils are of light weight and those from Western bases are heavier.

Cold Test.—This is the temperature at which the oil becomes so thick from cold that it no longer flows readily. It has nothing to do with the lubricating qualities after the oil is once in use, but may be of value when sufficiently low in case the engine has much exposed piping in which the oil may congeal if exposed to outside temperatures.

Practically all engine oils will thicken if exposed to a zero temperature and those which start to congeal at but little below freezing may make it difficult to crank an engine during the first start in winter weather. If it can be had without sacrificing other desirable qualities, a low cold test is an advantage.

Carbon Residue.—If a sample of oil is heated and maintained hot until the part remaining becomes hard and like carbon, this remainder is called the carbon residue and is measured in proportion to its weight in comparison with the weight of the original sample.

The carbon residue depends to a great extent on the viscosity of the oil and does not always indicate the amount of carbon that may be deposited in the engine because the conditions are not exactly similar.

Fire Point.—The degree of heat at which the oil takes fire and burns with a steady flame is known as its fire point or fire test. It varies with the flash point and by itself is of little value because an oil of low flash point will burn quickly regardless of the fire test, and with a high flash test the fire test will be correspondingly high.

Color.—The color of an oil before it is used in the engine or heated is of no value in indicating

its quality because almost any shade of color may be secured by the necessary filtering and bleaching during the refining processes.

Motor Cycle Oil Requirements.—Because of the exceedingly high temperature at which the motor cycle engine operates, it requires an oil that is different from the one used for automobile engine lubrication. Motor cycle oil must have a high flash and fire point. The flash point of oil should be 375° to 400° for cold weather and from 450° to 475° for warm weather. The fire point should be about 450° in cold weather and 525° in warm weather.

The motor cycle engine is subjected to both extremes of temperature because of its being air-cooled. In hot weather this engine reaches a very high temperature while in cold weather the metal of the cylinders rapidly falls to the same heat as the atmosphere. This makes it necessary that motor cycle engine oil have a low cold test so that there will be little danger of congealing during winter weather.

The motor cycle requires two different grades of oil, one an extra heavy body for warm weather use, and the other a heavy body for cold weather running. The viscosity at 210° F. would be about sixty for winter and one hundred for summer use. As a general rule, the manufacturers recommend that certain makes and grades of oil should be used in their machines and these recommendations should be followed. The mere fact that an oil at atmospheric temperature shows a heavy body does not necessarily indicate that it is suitable for motor cycle work because many of these oils were made

with the requirements of the water-cooled engine in mind and the automobile engine works at so much lower temperature that difficulty would be encountered. The normal temperature in the combustion chamber of the motor cycle engine is between 900° and 1000° F.

When operating a motor cycle in an especially cold climate or when the outside temperature is very low, it may sometimes be found that the oil recommended for cold weather use becomes so thick that much difficulty is encountered in starting the engine, and overheating takes place because of too slow feeding. In such a case, the oil may be thinned sufficiently for use by adding a small amount of kerosene. Care should be exercised to use as little kerosene as will allow the engine to operate and in no case should the proportion exceed one pint of kerosene to each gallon of oil.

OILING METHODS

Almost all of the earlier designs of motor cycle engines used a plain splash oiling system. By this method a certain quantity of oil was placed in the crankcase, this quantity being sufficient to raise the level to a point at which the connecting rod would strike the oil bath at each revolution of the crankshaft. This action served not only to lubricate the connecting rod bearing but also to lubricate all the remaining bearings and the cylinder walls by means of the oil spray resulting from the splash. This method, with various modifications, is still used in a majority of motor cycle engines.

The principal change in oiling systems is found in

the adoption of highly perfected mechanically driven pumps which maintain the correct supply of oil for the engine. With most of these systems the oil is sent either directly into the crankcase, into the timing gear case or else is forced first against the piston and the cylinder walls and then into the crankcase. One method of distribution is shown in Figure 40. Some

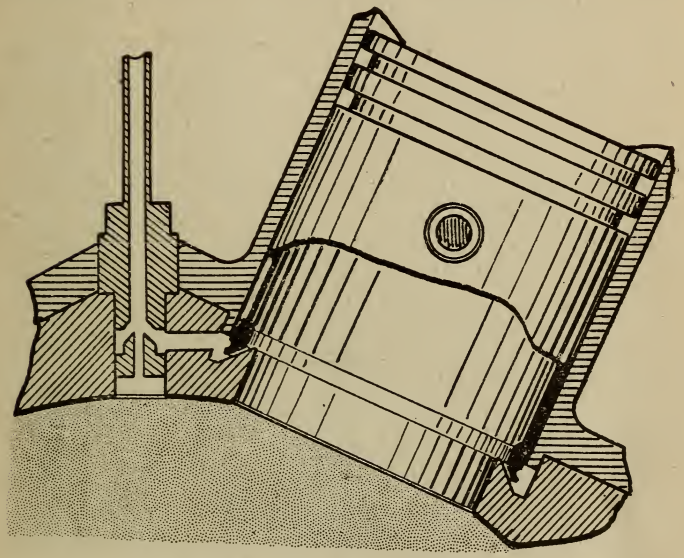

Figure 40.—Oil Distribution to Lower End of Piston in Norton Engine.

of the splash systems are of the circulating type in which oil is pumped from the reservoir into the crankcase and is then allowed to drain back into the reservoir to be once more circulated by the pump.

In many engines the crankcase vacuum is used to assist in the operation of oiling. On the upward stroke of the pistons a vacuum is created in the cylinder

below the piston and in the crankcase. This vacuum is controlled by the operation of a breather valve which is oftentimes mechanically operated from the timing gears. This vacuum is used to draw the lubricating oil to the cylinder walls from the oil vapor that exists in the crankcase due to the movement of the connecting rods. Because of the direction of rotation of the connecting rods and flywheels, one cylinder of a V type engine would receive more oil than the other cylinder. To prevent this excess of oil, many engines are fitted with a baffle plate which partially closes the lower end of the cylinder where it opens into the crankcase. The baffle plate used for the cylinder which would receive the most oil almost completely covers the opening, leaving but little more room than required by the connecting rod. The baffle plate for the other cylinder is made with much larger openings.

Some motor cycle engines are built to force oil directly to the principal bearings, that is, to the lower ends of the connecting rods and to the bearings of the crankshaft. This result is secured by drilling passages through the crankshaft and forcing the oil under pressure through these passages from which it escapes into the bearings. The excess of oil from the bearings is thrown off by centrifugal force and serves to lubricate the cylinder walls, the pistons, and the piston pins. Such a hollow shaft method of oiling a four-cylinder engine is shown in Figure 41, and one for a single-cylinder type in Figure 42.

The engine oil lubricates the valve actuating mechanism consisting of the cams, the valve-lifters and the timing gears. This oil is also generally used for lubricating other gears contained in the crankcase, such as those used for driving the magneto. In some designs

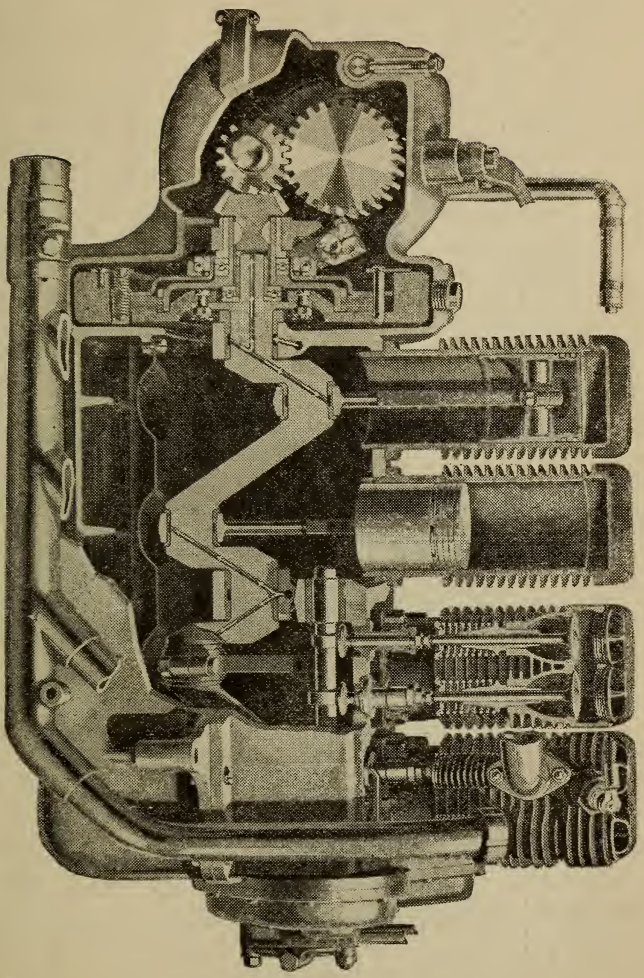

Figure 41.—Force Feed Oiling System With Ducts Drilled in Crankshaft (Henderson).

this oil is used even after escaping from the crankcase. In a typical design the operation is as follows: The oil in the motor case is subjected to a slight pressure,

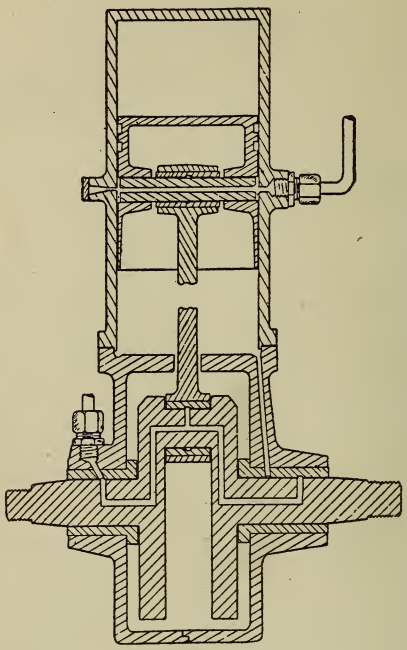

Figure 42.—Drilled Crankshaft and Piston Pin of Levis Engine.

which is relieved through the compression release valve as the piston commences to descend. The oil from the motor base then enters the timing-gear case and lubricates the gears and other working parts within it. The surplus oil passes out through the air relief tube and oils the short drive chain.

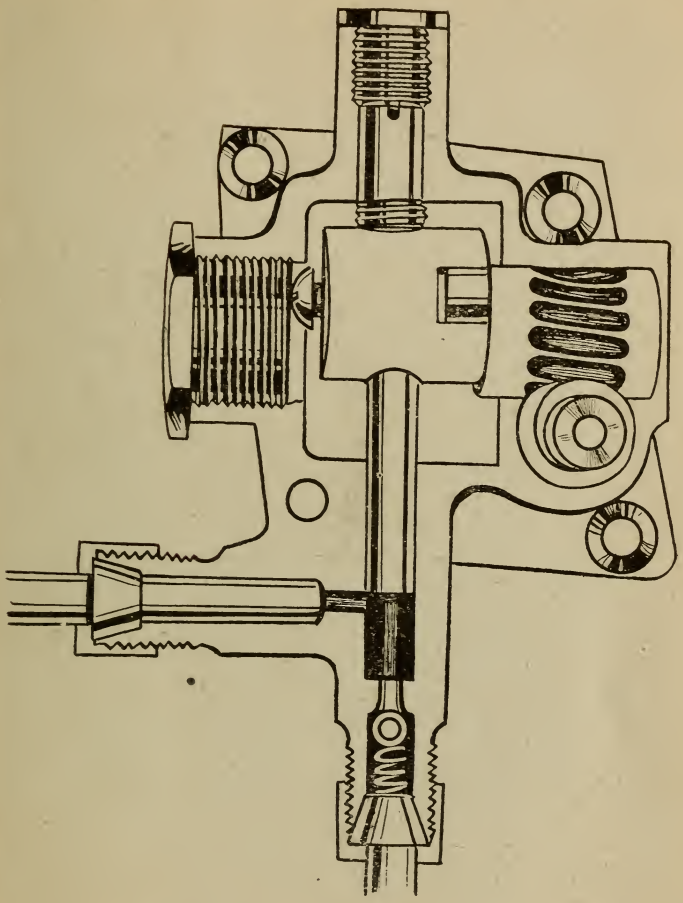

Figure 43.—Worm Gear Driven Plunger Oil Pump (Reading Standard).

ENGINE DRIVEN PUMPS

The majority of motor cycle lubrication systems make use of a plunger type of pump. One such design

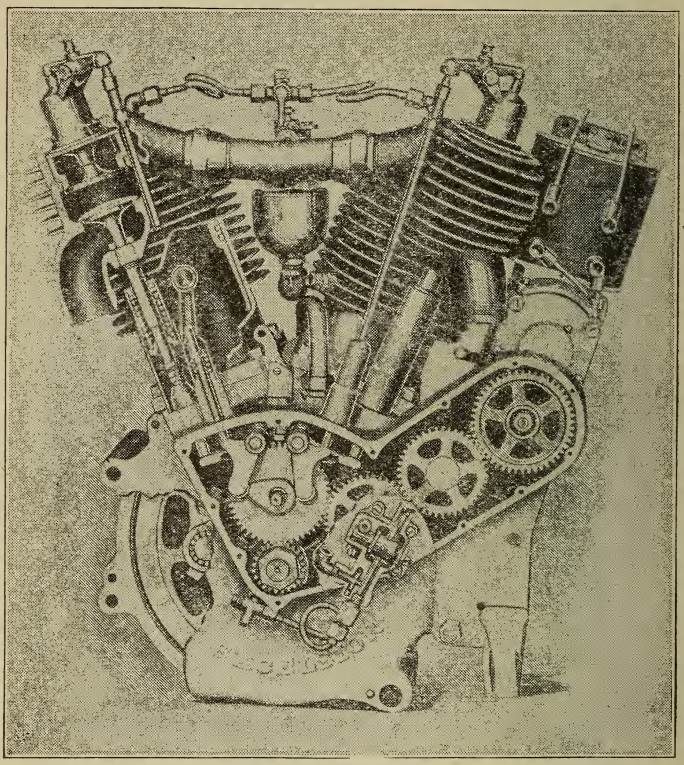

Figure 44.—Position of Oil Pump on V-Type Engine (Excelsior).

is shown in Figure 43. The plunger is raised and lowered by a worm-driven eccentric shown at the right hand side of the illustration. As the plunger is

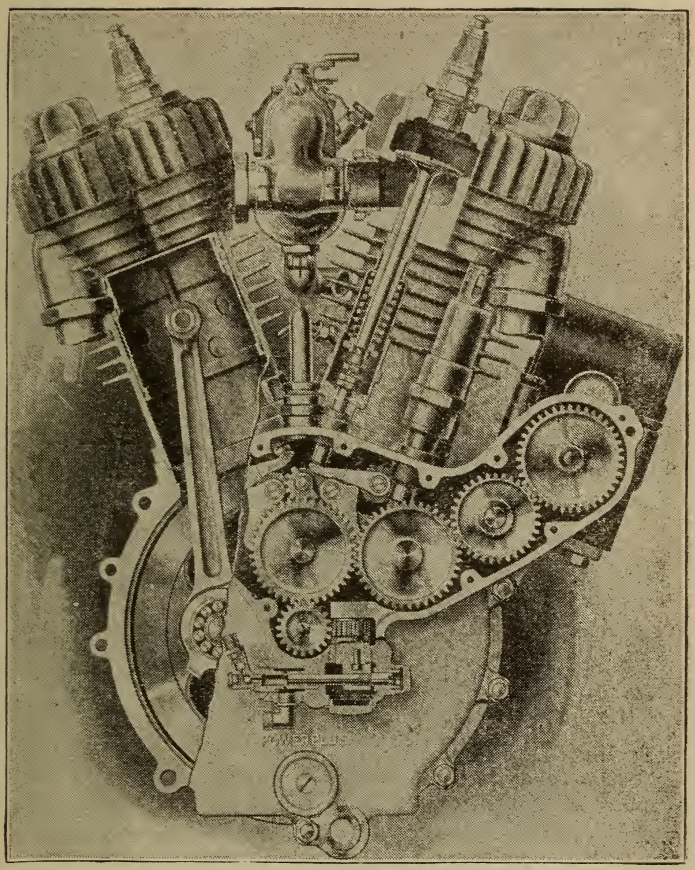

Figure 45.—Oil Pump Mounting on Indian Engine.

raised, it draws a charge of oil into its barrel through the pipe coming from the tank. Within this pipe is a ball check valve (not shown). Oil is not drawn from the lower pipe because the ball valve in that pipe is drawn closed by the receding plunger and is held closed by a small coiled spring. When the plunger descends, the ball check in the left-hand pipe is closed while the lower valve is forced open, thus discharging the oil into the lower pipe. The amount of oil feed is adjusted by changing the amount of travel given the plunger.

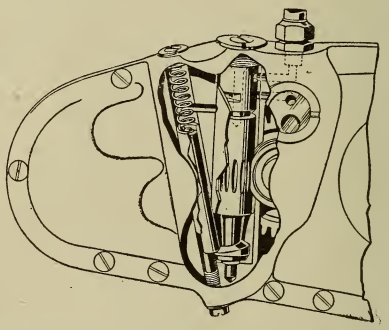

Figure 46.—Cam Operated Plunger Oil Pump (Harley-Davidson).

The location and adjustment of a plunger oil pump similar to the one just described is shown in Figure 44, while a slightly different disposition of the parts in the plunger pump is shown in Figure 45. A plunger pump in which the piston is raised by means of a spiral cam and is returned by a coil spring upon its escapement from the cam is shown in Figure 46.

A somewhat novel form of oil pump is shown in Figure 47. It is a plunger and cone revolved in a socket by a ratchet operated from the valve lifter. The spring operated plunger within the cone is with-

drawn by a cam surrounding the plunger, and when it slides off the cam the spring drives the plunger down, discharging the oil from the chamber into the crankcase.

Pump Adjustment.—The exact method of changing the oil pump feed in different machines is best learned from the makers' instruction books. With the oil

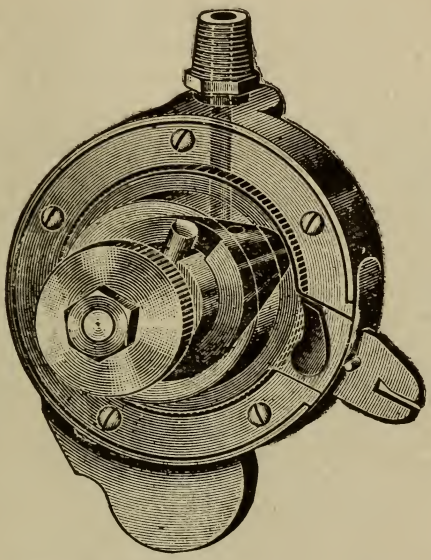

Figure 47.—The Iver-Johnson Oil Pump.

pump once correctly set for service conditions, there should be little, if any, need for changing this adjustment until the pump wears or until a decidedly different grade of oil is adopted. Should it ever become necessary to use light weight oil, adjustment will probably be needed because otherwise an excess of lubrication will be sent into the engine. There may be

some wear and leakage at ball check valves and it is advisable to replace the old balls with new ones once a year.

It will be found that the use of a side car will call for a great volume of oil being fed to the engine. It will generally be found that the use of a side car will call for about one-third more oil than is needed by the same machine ridden only in solo work.

If it is found that the oil level in the crankcase shows a persistent gain after a considerable amount of riding, it indicates that the pump is feeding too

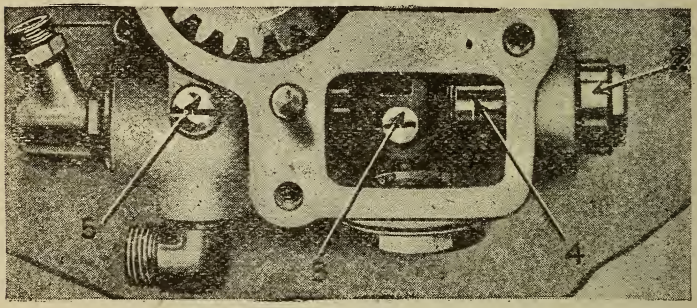

Figure 48.—Adjustments of Indian Oil Pump. 2: Cap on End of Pump. 3: Lock Screw. 4: Plunger. 5: Vent Plug.

much while if it is necessary to make frequent additions by means of a hand pump, it indicates that the mechanical oiler is feeding too little. In either case an adjustment is called for. In making the oil pump adjustments do not change them more than a turn at a time and after doing this, tighten the locking devices, close the pump, and ride a sufficient number of miles to know whether the wrong conditions are being corrected. Typical oil pump adjustments are shown in Figures 48 and 49.

Air Locks.—When, for any reason, there is a failure of the oil supply to a mechanically operated pump of the type generally used, the pump will become emptied of liquid and an air lock will be formed in the oil passages or pipes. After that, even with the oil sup-

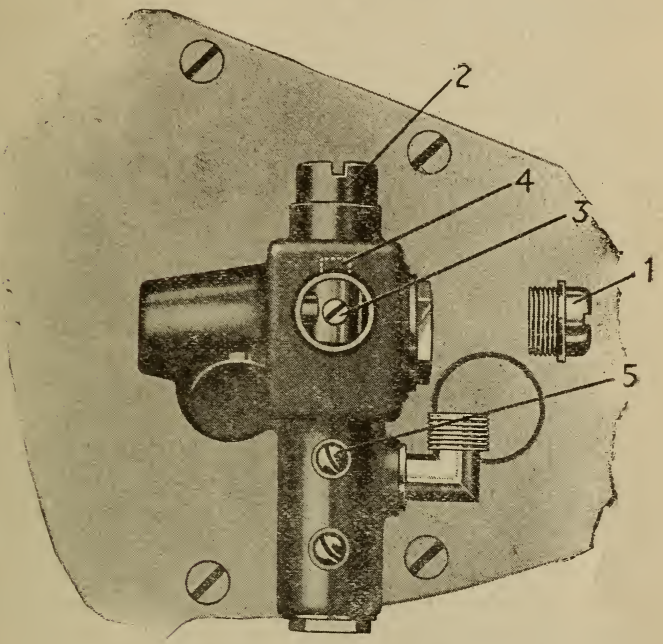

Figure 49.—Adjustment of Oil Pump on Indian Scout. 1: Cap on Side of Pump. 2: Cap on Top of Pump. 3: Lock Screw. 4: Plunger. 5: Vent Plug.

ply again reaching the pump, incorrect lubrication will follow until the air that has been trapped in the passages is allowed to escape. Most pumps are provided with openings for use under such conditions. With the screws or plugs removed from these vent

openings and with a plentiful supply of oil in the reservoir, the pump should be allowed to operate until there is once more a free flow either into the crankcase or through the vents to the air. With the oil flowing freely the vents may be closed and any disconnected pipes replaced. An air locked pump will often overfeed.

HAND PUMPS

Many machines are fitted with a hand operated plunger pump used either as a sole means for sending oil to the engine or as an auxiliary means in addition to the engine operated pump. When the hand pump is fitted as an auxiliary it is used to supplement the power driven pump under conditions which the power pump would be unable to meet without a change in its adjustment. The hand pump is used when climbing long hills, when pulling through deep sand or mud and when using the low or intermediate gear ratio over any great distance. The hand pump is also used when the machine is being driven at high speeds for long distances, this generally applying to speeds in excess of forty miles an hour. The attachment of a side car when the mechanical pump has been adjusted for solo work will call for frequent additions of oil made by the hand pump.

If the hand pump is used as a sole means for giving oil to the engine, one pumpful for each ten to fifteen miles driving will generally be required. The rider will soon learn to gauge the distance that one pumpful of oil will carry the machine and will then be governed accordingly. In using the hand pump, the plunger should be drawn up quite slowly so that oil and not air will be drawn into the pump. The downward

stroke should be made at a moderate speed and it should be steady from beginning to end. If the pump is operated too fast, it will draw more air than oil and the lubrication of the motor may be insufficient. In all cases it is advisable to give the engine about one-half pumpful at each injection and to do this twice as often as a full pump would be used.

Hand oil pumps are sometimes built in such a way that the pump draws a charge of oil into a barrel from which the oil is fed to the engine by a drip feed, this drip feed being adjusted to give a certain number of drops per minute. With such an outfit, the drip feed adjustment may be set to suit the operating conditions. If solo running at ordinary speeds calls for a barrelful of oil each five miles, side car work would require a barrelful every four miles, and racing about every three miles. Three speed models require more oil than machines having but one gear ratio because of the extra running in low and intermediate with the three speed machine. When using a drip feed oiler care should be exercised to shut off the oil whenever the engine is idle even if it is only for a short time.

OIL RENEWAL

Because of the exceedingly poor grade of gasoline that is now available there is a certain portion of the fresh mixture that is not burned in the engine and that finds it way into the crankcase oil. This dilution of the oil destroys its body and lowers the flash point with the result that the engine loses compression and power while the fuel and oil consumption increase. If neglected, this condition soon results in worn cylinders, pistons, piston rings, shafts and bearings with

all the attendant troubles. Carbon deposit, both above the piston and in the crankcase, increases rapidly and the engine shows a general all-around poor condition.

The trouble described may be prevented to a great extent by using a correct oil which will form a tight piston seal around the rings and by keeping the engine as warm as possible without overheating. The choker used while starting should not be kept closed for any longer than necessary to get the engine under way because this draws a charge rich in liquid fuel. Finally, and of the greatest importance, the oil should be drained from the crankcase and replaced with fresh at regular intervals.

After a new machine has been driven four or five hundred miles, the oil should be drained; and, thereafter, at the end of each thousand to fifteen hundred miles running, a similar procedure should be followed. Should the motor cycle be used for short trips with frequent starts and stops, or if it is used a great deal during cold weather, the draining should be done oftener than just mentioned.

The drain plug or valve in the bottom of the crankcase should be opened and all of the oil allowed to run out. The opening should then be closed and gasoline poured into the crankcase. The engine may then be cranked for about a minute in order to wash out the oiling system, and the gasoline then be drained as was the oil.

After the gasoline has been completely drained, the oil level should be brought to its usual height by the addition of fresh lubricant.

Such draining is essential during cold weather because of the fact that a certain amount of water results from the combustion of the gases and this

water will quite likely settle in the crankcase where, even if it does not mix and emulsify with the oil, it may possibly freeze.

CHAPTER IV

THE FUEL SYSTEM

Parts of the motor cycle which are used to furnish a combustible gas to the engine cylinders include a fuel tank, an inlet manifold or pipe between the cylinders and the carburetor, the carburetor itself and the necessary feed pipes, valves and strainers, all of these being seen in Figure 50.

FUEL

Present day gasoline consists of a mixture having various characteristics of weight and evaporative qualities. Gasoline is described by mentioning its weight in relation to water according to degrees of the Baume scale, also its boiling points. Gasoline has an initial boiling point at which the first vapors are formed and a final boiling point at which the liquid is completely evaporated.

The weight or gravity of the fuel does not mean a great deal as to its suitability for use in an automobile engine, this being true for reasons that will be explained. On the other hand the boiling points have a great deal to do with easy starting and general satisfactory performance.

When the crude petroleum is distilled at the refinery, a number of products are secured. Among the most familiar are lubricating oils, kerosene and gaso-

line. One of the chief differences between these three products, taken as examples, is in their weight or specific gravity.

The weight of "gasoline" represents the average of

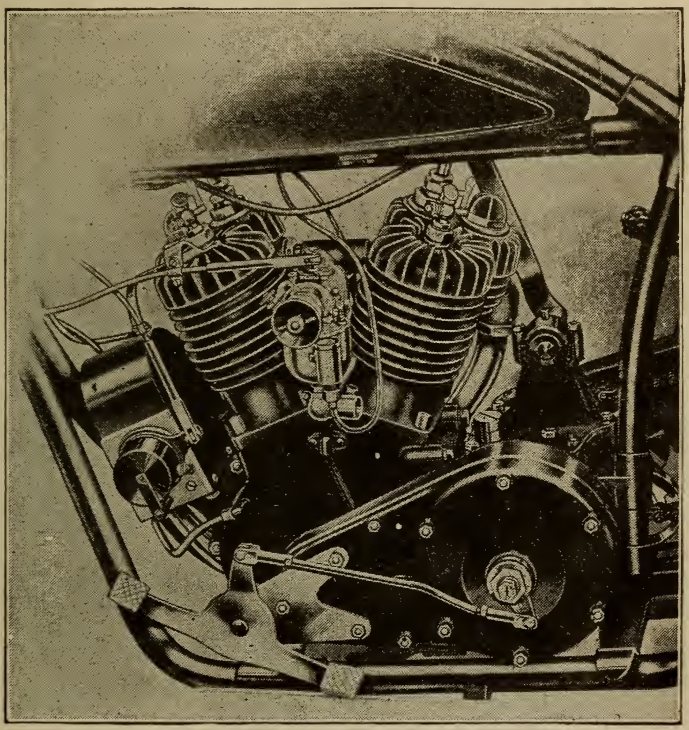

Figure 50.—Carburetor Mounting Between the Cylinders of V-Type Engine (Indian).

the oils of which the fuel is composed. Thus, 76 degree gasoline and 40 degree kerosene, in equal parts, would make a liquid which could be called 58 degree gasoline.

As everyone knows, kerosene is hard to burn in a gasoline engine, while good gasoline is easily burned. Inasmuch as the above mixture is in reality half kerosene, that half will be difficult to burn.

Gasoline is a physical mixture and not a chemical one. If a certain quantity of the liquid be exposed to the air it will, of course, evaporate. First the gasoline will disappear leaving kerosene and oil, next the kerosene will disappear and only an oily deposit will be left.

The initial boiling point is the temperature at which the gasoline starts to vaporize. It will be readily realized that the lower this temperature, the easier the fuel will ignite because the liquid must be vaporized before it will take fire. This initial boiling point varies between 125° and 200° F. Final boiling points run from 325° to 500°.

In order to secure easy starting, smooth running, and comparative freedom from carbon deposits it is apparent that a low initial boiling point and a low final boiling point will be desirable. This is secured in good fuel, but in a blend composed of low grade kerosene and high grade gasoline, it cannot be secured. Such a blend would have the initial boiling point of the gasoline, which might be around 150°, but it would have an end boiling point like that of the kerosene which might be around 500° in actual practice. An initial boiling point of 125° to 150° and an end point of about 350° will give good results.

The gasoline secured from filling stations and garages generally has a gravity not above 54°. It is also possible to secure high test fuel having a gravity between 60° and 64°. This high test gasoline not only facilitates starting but it has less tendency to dilute

the lubricating oil in the engine crankcase. High test gasoline is more easily volatilized and ignites to make a more complete combustion and less unburned products than does the low-test fuel. At temperatures below 20° F., the low-test fuel will be difficult to ignite when the engine is cold, and below zero it will be practically impossible to ignite it for starting.

In very warm weather, the high test fuel shows a considerable loss by evaporation in the carburetor and in the tanks, and it is therefore somewhat uneconomical. Very light gasoline may even boil in the carburetor during hot weather.

The tank is generally carried in the frame and just above the engine. It has an average capacity of between two and one-half and three gallons. The manifold is of simple construction with motor cycle engines; in the single-cylinder V type twins consisting of only a short length of pipe, and in the four-cylinder types showing little or no complication when compared with similar parts used for automobile engines. The pipes and valves require no special explanation. This leaves the carburetor as the principal and the most interesting part of the fuel system.

CARBURETOR PRINCIPLES

It is the purpose of the carburetor to transform the liquid fuel into a vapor or at least into a spray composed of very fine particles. It is the further purpose of this instrument to mix the fuel vapor with a quantity of air such as will produce a mixture which will give the desired power while burning.

The low grade of fuel that is available has introduced many difficulties into the problem of carburetor

design. On the first motor cycles the fuel mixture was produced by an arrangement called a mixing valve in which a jet of gasoline was allowed to enter a stream of incoming air. The gasoline of that day was so volatile and so highly inflammable that this simple arrangement gave good results.

All of the modern carburetors include two principal

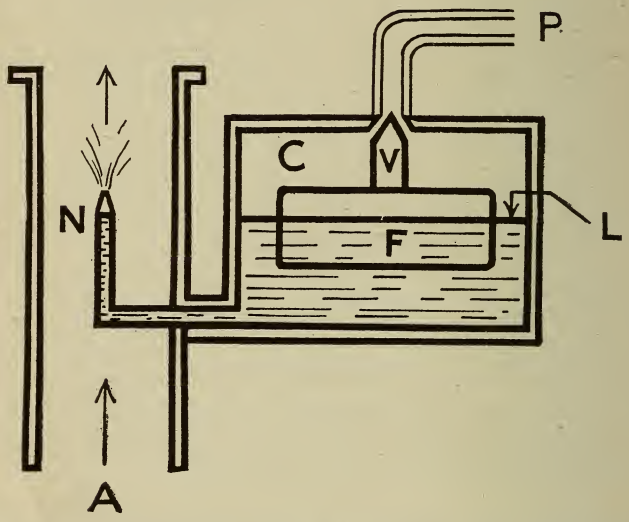

Figure 51.—Elementary Parts of a Float Feed Carburetor. A: Air Inlet. C: Float Chamber. F: Float. L: Float Level. N: Nozzle. P: Fuel Pipe.

parts in their make-up. One of these parts consists of a jet or opening through which comes the liquid fuel as it enters the air stream and this jet is enclosed within the air tube. The second part includes an automatic valve which is operated by a float in such a way that a fixed level of liquid fuel is maintained within the body of the carburetor. These elementary parts

are shown in Figure 51. Referring to the illustration, liquid fuel comes from the supply tank through the pipe *P*. This liquid passes into the float chamber *C* through the float valve *V*. When the liquid has risen to a height called the float level, and indicated by the line *L*, the float *F* has risen high enough to cause the float valve to shut off the flow of incoming fuel. The liquid level has now risen to a point in the nozzle end which corresponds to the float level in the bowl. Outside air is drawn in at the point *A* and travels through the air tube in the direction indicated by the arrows. The upper end of this tube is connected with the combustion chamber of the engine through the manifold and the inlet valve. Suction or partial vacuum created in the air tube by the descent of the piston on the inlet stroke causes a spray of liquid fuel to issue from the jet and to mix with the air stream. These parts would make up the simplest possible type of float feed carburetor.

It is necessary that the proportions of the fuel mixture be practically unchanged over wide ranges of engine speed and the carburetor just described would not meet this condition. The jet opening could be proportioned in relation to the air tube to make a perfect mixture for one certain air velocity or engine speed. If the speed were to be either increased or decreased, then the proportions of fuel and air would undergo a decided change. With an increase of suction the flow of fuel from the jet or nozzle would increase in a certain ratio but this same suction would not serve to increase the flow of air in the same ratio. The air would become thinner and the mixture would then be too rich in fuel. With a decrease in speed, the volume of air would not decrease as rapidly as

would the volume of fuel and the mixture would then become too weak for proper operation of the engine. There are three principal ways in which this difficulty may be overcome and these three ways allow all carburetors to be placed in one of three classes.

AIR VALVE CARBURETORS

The first class provides additional air at high speeds and reduces this additional air as the engine speed decreases. Such an instrument is shown in Figure 52. Referring to the upper drawing of this illustration, the air passage and the fuel nozzle may be seen in the center of the carburetor. The upper end of the nozzle is fitted with an adjustable needle valve which serves to regulate the flow of fuel from the nozzle. Referring to the lower left-hand drawing, the float may be seen surrounding the central air passage and the float valve which closes the fuel inlet is shown at the right of the carburetor. Again referring to the upper drawing, it will be seen that after the incoming air has passed around the nozzle and taken up a supply of fuel spray, this air passes to an upper chamber and thence through a throttle valve at the right into the inlet manifold of the engine. At the left-hand side of this upper chamber is a valve called the auxiliary air valve. This valve opens inwardly under suction and is normally held on its seat by the coiled spring which is clearly shown. The tension of this air valve spring may be adjusted by the thumb screw shown at the extreme left.

As the speed of the engine increases, the flow of liquid fuel is rapidly increased in volume while the flow of air around the nozzle does not increase to such

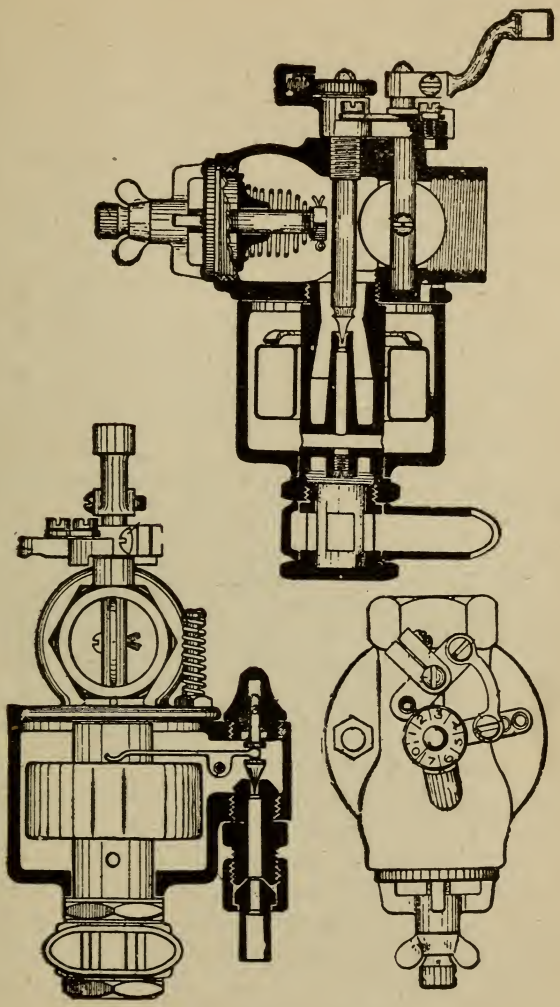

Figure 52.—Construction of Breeze Motor Cycle Carburetor.

an extent. The mixture therefore, requires additional air. The same suction that increases the fuel flow serves to draw the auxiliary air valve away from its seat and the required amount of air is admitted through this valve and mixes with the volume of air and fuel coming from around the spray nozzle.

The carburetor just described has two adjustments; one for the auxiliary air and the other for the amount of fuel passing through the nozzle. The fuel adjustment is by means of the needle valve which partially closes the upper end of the nozzle. This fuel adjustment is generally used for regulating the mixture at low engine speeds while the auxiliary air valve adjustment is used for securing a correct mixture at high engine speeds.

One of the best known carburetors employing an auxiliary air valve is shown in Figure 53. A section through the air valve alone is shown in the lower left-hand drawing, the valve being indicated by *A* and a special manual adjustment by *12*. This carburetor embodies a unique feature in that the fuel needle valve is moved by movement of the throttle so that as the throttle is opened more and more to admit a greater volume of mixture to the engine cylinders, the needle valve is raised farther and farther from its seat in the upper end of the nozzle, thus admitting more fuel to the mixture. The needle valve is raised and lowered by a pivoted lever one end of which surrounds the valve stem while the other end rests against a cam operated with the throttle. The contour of this cam is changed by the adjustment shown in the upper left-hand drawing and indicated by *Z*.

To adjust this carburetor for low speed, see that the leather air valve *A* seats lightly; then turn knurled

button *I* to the right until the needle *E* seats in the spray nozzle, cutting off the flow of gasoline. Now turn *I* to the left about three turns and open the low speed air adjusting screw *L* about three turns. Then open the throttle about half way to start the engine.

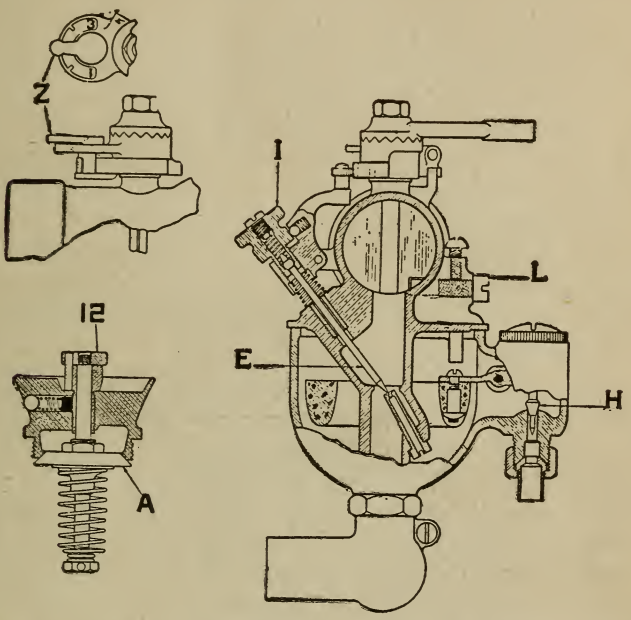

Figure 53.—Construction and Adjustments of Schebler Model H Carburetor.

After starting the engine, close the throttle and turn the needle valve adjusting screw *I* to the right until the mixture becomes so lean that the engine backfires or misses. Then turn the adjusting knurl *I* to the left, notch by notch, until the engine runs smoothly. If the engine runs too fast with this low speed adjust-

ment, turn the low speed adjusting screw *L* to the right.

The carburetor is now ready for the high speed adjustment and the throttle and spark should be advanced. The adjustment is now made by the pointer *Z* which, as it moves from *1* to *3*, increases the supply of gasoline. Moving the indicator from *3* to *1* cuts down the flow of gasoline. When the indicator reaches the right point, the engine will run without missing or backfiring. If, when lever *Z* is turned to *3*, the mixture is still too lean, and causes the engine to backfire, increase the tension of the air valve spring by turning the air valve adjusting screw *12* to the left. The high speed air valve on the side of the carburetor is to be used only for extreme high speed. This valve should be kept closed when adjusting the carburetor.

The air valve can be locked in a closed position which materially helps in easy starting. It operates by pulling out the knurled button *12*, and giving it one-quarter turn. When the engine is started, turn the button *12* back. This releases the air valve *A* and allows it to operate in the customary manner. The locking feature of the air valve does not in any way alter the instructions for adjustment of the air valve. When first starting the engine, if it backfires on account of being cold, do not readjust the carburetor but wait until the engine warms up.

PLAIN TUBE CARBURETORS

In the second class of carburetors there is no auxiliary air valve nor are there valves of any other kind except for the throttle which controls the volume of

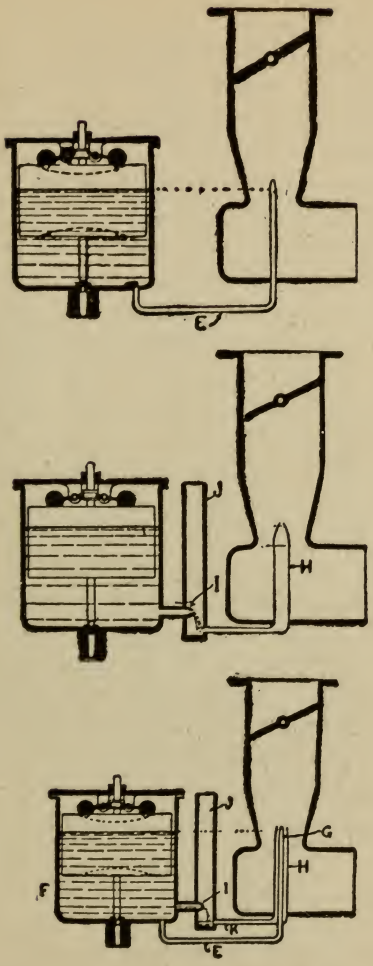

Figure 54.—Operating Principle of the Zenith Carburetor.

mixture sent to the engine. This is known as the plain tube type carburetor. One of the best known examples is shown in Figures 54 and 55.

The principle upon which the Zenith carburetor operates may be understood by reference to Figure 55. The elementary type of carburetor shown at the top in Figure 54 consists of a single jet or spraying nozzle placed in the path of the incoming air and fed from a float feed device. While it might be supposed that, with increase of engine speed, the flow of both gasoline and air would increase in proportion, this is not actually the case. The flow of gasoline increases in almost direct proportion to the engine speed but because the increase of suction or vacuum tends to draw the air out thinner and thinner, the actual quantity of air does not increase in any such proportion and the mixture of gas supplied by such a carburetor would become richer as the speed increases.

Referring to the center drawing Figure 54 it will be seen that, between the float bowl and the jet, has been placed a well *J* which is open to the outside air and through which the gasoline passes by way of the opening *I*, thence passing as before to the jet *H*. It will be realized that the maximum amount of fuel that can reach the jet *H* will be determined by the size of the opening *I* without regard to the suction existing around *H* because the flow through *I* is not directly acted upon by this suction. With such a device the air flow will increase with speed of the engine; and while it will not be in direct proportion, there will be an increase over the whole range of engine speed. Now, inasmuch as the flow of gasoline cannot increase beyond a certain amount, while the flow of air will increase, the mixture furnished by such an arrange-

ment will become weaker with increase of engine speed.

In the Zenith carburetor these two types of jets are combined as shown in the lower drawing. The direct suction, or richer mixture type, leads through pipe *E* and nozzle *G*, while the limited flow device

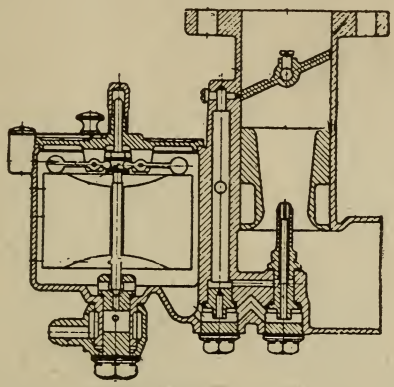

Figure 55.—Construction of Zenith Carburetor.

consists of the well *J*, opening *I*, passage *K* and jet *H*. As the flow of fuel from jet *H* counteracts the change in the flow from jet *G*, the complete mixture may be made practically of constant proportions over all ranges of speed.

There are four variables used in making the initial adjustment of a Zenith carburetor. One of these is the choke tube which is the passage surrounding the jets. Another is the main jet which controls the flow of fuel at high speeds. A third is the idling jet which in Figure 55 is shown just at the left of the main jet. The fourth adjustment is the idling well which controls the air flow at low engine speeds. With these

four adjustments once determined for an engine they are put into place in the carburetor and remain there without change or alteration.

MANUAL CONTROL CARBURETORS

In the third class of carburetors, the additional air required at high engine speeds is controlled by means

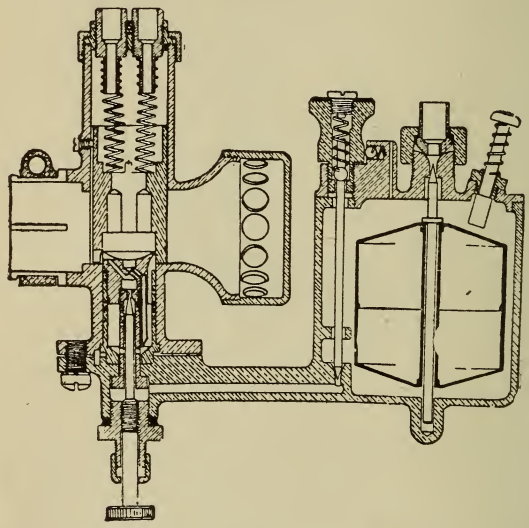

Figure 56.—Construction of Schebler Model AL Carburetor.

of a manually operated valve. This means that there are two carburetor controls within reach of the rider. One of these controls is for the throttle while the other is for the extra air.

One such carburetor is illustrated in Figure 56. This instrument is made with a two-piece piston throttle, one being used as a throttle and the other as an air choke for starting and warming up the engine.

To make an adjustment, first turn on the main needle on the top of the carburetor three or four turns; then open the low speed needle on the bottom of the carburetor about one and one-quarter turns from its closed position.

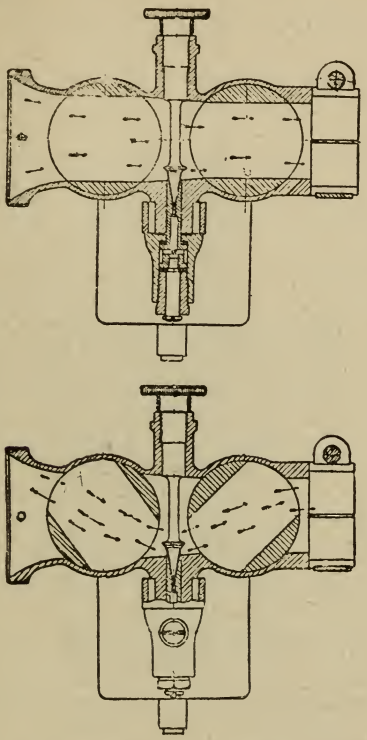

Figure 57.—B. S. A. Carburetor Shown With Throttle and Air Control Wide Open at the Top and With Both Controls Nearly Closed at the Bottom.

Start the engine by flushing the float bowl and after the engine has become thoroughly warmed up, adjust the main or high speed needle on the top of

the instrument, cutting down the fuel supply until the engine backfires. Then turn on a little more gas a notch at a time until the engine runs smoothly and the proper adjustment will have been secured for high speed. Next adjust the low speed needle, located at the bottom of the carburetor, until the desired low

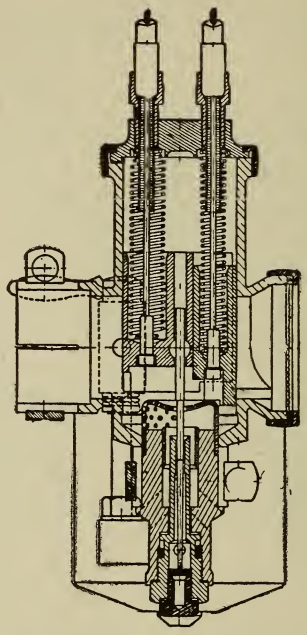

Figure 58.—Construction of B. & B. Carburetor, Showing Throttle and Air Controls.

speed is secured. No further adjustments are required.

Another example of the third class of carburetors is shown in Figure 57. It will be noted that the whole of the air under all conditions is drawn across the jet. The air and throttle valves are in effect two cylinders with through ports bored so that when the two valves

are fully open they virtually constitute a tubular passage from air inlet to engine.

The upper drawing shows the valves fully opened, in which position the carburetor presents no obstruction to the free passage of the mixture. The lower drawing shows the valves partly closed. It will be noted that the air is drawn down and directly across the jet, then upwards through the throttle to the engine. At all speeds the engine suction is concentrated across the jet.

In operating such a carburetor as just shown, the air valve is closed for starting and is then opened sufficiently to secure a good running mixture. More power is secured while running by either gradually reducing the air opening or gradually increasing the throttle opening. The jet opening is adjusted by a needle valve shown in the center of the carburetor.

Still another type of the third class of carburetor is shown in Figure 58. Referring to the illustration, it will be seen that this carburetor is adapted for a double lever control, one lever of which controls the throttle and the other the air valve. The construction of the throttle is such that when opening it, it also opens sixty per cent of the total available amount of air, so that the maximum amount of extra air that is under control by the air valve only amounts to forty per cent instead of the usual hundred per cent. To the throttle valve is attached a needle which works in the jet so that as the throttle is raised or lowered, the needle is likewise raised or lowered.

The needle is compound in shape, the first portion being parallel and after a certain distance becoming tapered, which taper continues to the end of the needle. The jet in which the needle slides is situated

in a small choke tube admitting an amount of air sufficient to break up the gasoline as it issues from the orifice. Fitted in the throttle and completely enclosing the top of the choke tube is a cap into which the gasoline spray and air pass from the jet and choke. This cap is provided on one side with many holes of small diameter through which the gasoline and air have to pass. In Figure 59 is shown the float construction used with the carburetor just described.

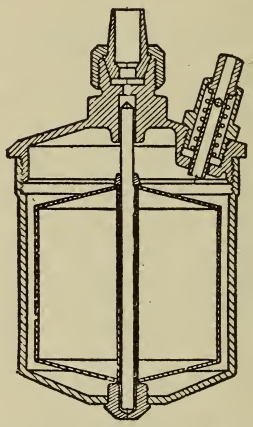

Figure 59.—Float Mechanism of B. & B. Carburetor.

TROUBLES WITH THE FUEL SYSTEM

Extreme cold weather may make the operation of starting an air-cooled engine quite difficult. Under such conditions it is advisable to inject a small quantity of gasoline directly into the cylinders through pet cocks or through the spark plug openings. The engine can then be cranked with the pet cocks open. The gasoline frees the congealed oil and the engine can be cranked rapidly enough to obtain a good start-

ing spark. As soon as the engine commences to fire, the pet cocks can be closed.

While it is possible to control the speed and power of the engine by means of the compression release, this is not good practice because with the exhaust valve raised in this manner, hot gases are continually flowing over the valve face and seat and this will cause rapid pitting and burning.

It will often be found that long continued riding at high speed will cause the engine to apparently lose a great deal of its power, this effect being due to insufficient lubrication. Better action will be secured if the throttle is partially closed for an instant once every mile or two. This closing of the throttle produces a high vacuum in the cylinders and this vacuum assists in bringing an additional supply of oil up over the cylinder walls.

Among the troubles which may be found in the carburetor and which are not due to an incorrect adjustment are the following: Dirt or water may have entered the float bowl, or the strainer at the fuel inlet may have become clogged. The connection between the float and the float valve may have become bent so that the level of fuel in bowl is either too high or too low. The float itself may have become punctured if made of metal or it may be fuel soaked if made of cork. In either case the fuel level will be too high and the mixture will be too rich. Should benzol be used in a cork float carburetor the float should be covered with collodion because the benzol will dissolve shellac. It may also be found that the float or the float valve will stick in certain positions or that dirt may have lodged between the valve and its seat.

The spray nozzle may be clogged with dirt or some foreign material may have lodged between the nozzle opening and the adjusting needle valve. In some cases the throttle may be loose on its shaft or the controls may have loosened so that the throttle does not open and close properly. It is also possible that the stop screw which prevents complete closing of the throttle is not properly set. With an old carburetor there may be a considerable leakage of air past the throttle shaft openings.

In carburetors using a choke valve of the butterfly type by means of which incoming air is shut off while starting, it may be found that the choker does not close tightly enough or that it does not remain fully open when released. Continued cranking with the choke closed or excessive priming of the cylinders with liquid fuel may act to prevent starting. The air valve should be examined to see that its springs are not broken and that the valve stem does not bind in any position. Any bending or jamming of the air valve will prevent the carburetor from furnishing a correct mixture and if the air valve stem or its guide have become very much worn, the mixture will be too weak at low speed.

Difficulty will be encountered at low speeds should the inlet manifold or its fastenings become loose. If gaskets are used they must be clean and whole. A failure of fuel at the carburetor may result from a stoppage of the vent through the filler cap of the fuel tank because it is necessary that air flow into the tank in order that fuel may flow out of it. Any dirt or other obstructions in the fuel tank, in the outlet valve, or in the pipe to the carburetor will result in a poor mixture at high speeds.

CHAPTER V

MAGNETO IGNITION

Two types of ignition are in use. One of these types, which will be described in this chapter, uses a magneto for the source of current while the other type, to be described in the following chapter, uses the lighting dynamo and a storage battery as sources of current.

A magneto ignition system as shown in Figure 60 includes the magneto itself, the necessary wiring connections and the spark plugs in each of the cylinders of the engine.

In order to produce a spark within the cylinder of the engine it is necessary that the electric current jump across a small gap in the spark plug which is inside the cylinder and surrounded by the gaseous mixture. A current of extremely high pressure or voltage is required in order to pass across this gap because the resistance of the mixture is so great that no ordinary voltage has any effect. The pressure of the current from either of the primary sources used for ignition is never more than from six to fifty volts, but this current of low voltage is of comparatively great volume or amperage, and is used to produce another current having voltage sufficiently high to pass across the gap, through the mixture, and in so doing produce the heat of the electric spark. The required high voltage or high tension current is

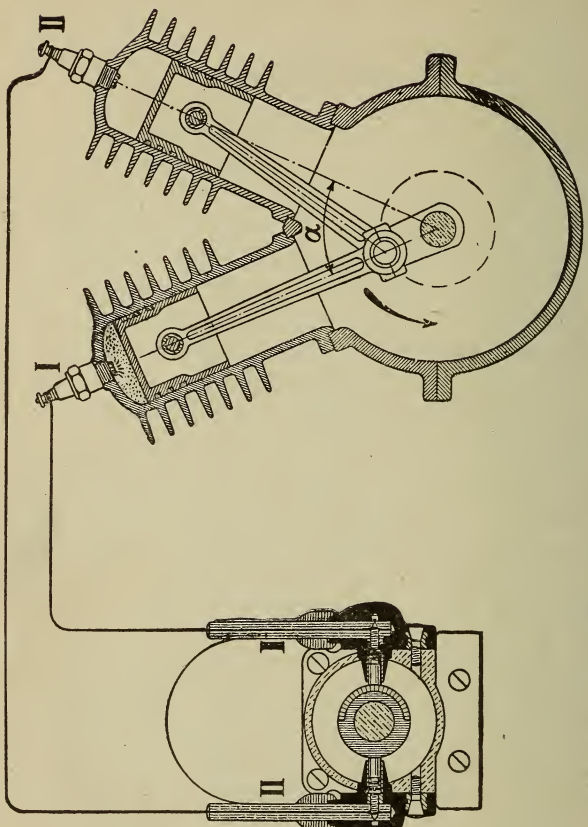

Figure 60.—Magneto Ignition System for Twin-Cylinder V-Type Engine (Bosch ZEV).

secured by induction from the primary current of low voltage.

It has been found that any change in the strength of a magnetic field within which is a coil of wire will cause electric currents to be induced in the coil, the strength of these currents depending on the intensity of the magnetism, and on its degree of change.

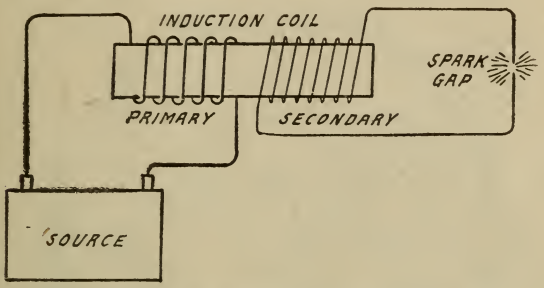

Figure 61.—Principle of the Induction Coil.

When a current of low voltage is passed through the primary winding of an induction coil as in Figure 61 there is a current generated in the secondary winding, but this current which is induced by completion of the primary circuit is not of sufficient strength to cause a spark in a cylinder. When, however, the circuit through the primary winding is broken and the current ceases to flow, there is a very powerful action in the coil and a high tension current is induced in the secondary winding with sufficient voltage to cause the current to pass across the spark gap and ignite the mixture.

THE BREAKER

It has been explained that the greatest voltage is secured from an induction coil at the instant the pri-

mary circuit is broken. That part of the ignition mechanism which causes this break is called the contact breaker, circuit breaker or interrupter. A typical breaker is shown in Figure 62.

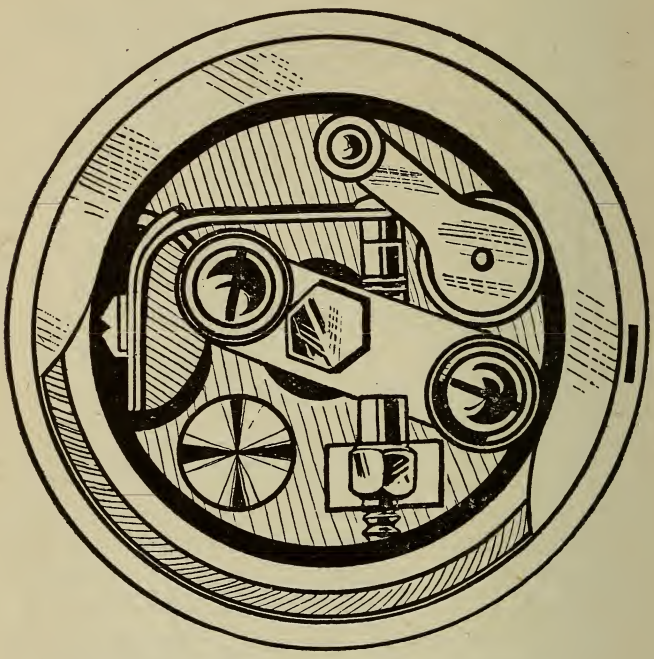

Figure 62.—Breaker of the C. A. V. Magneto.

The principal parts of the breaker include two contact pieces through which the primary circuit for the induction coil passes while these contacts are touching each other. When separated, the contacts prevent a further flow of this primary current. In connection with the contacts, or as, they are often called, the contact points or simply the points, there is a cam which

causes their separation at the instant a spark is desired in one of the engine cylinders. All of the remaining parts of the breaker are for the purpose of allowing the contacts and the cam to operate properly.

One of the contact points is stationary while the other is movable. The stationary contact is securely mounted on the body of the breaker and is the member provided with means for changing the distance between the points when separated, that is, the stationary contact is adjustable. The other contact is moved to open and close the circuit and is not adjustable.

It is necessary that the contact points separate a certain distance from each other when the circuit is opened by the breaker, this distance usually being in the neighborhood of fifteen to twenty thousandths of an inch.

The time at which the spark passes at the gap in the plug is determined by the instant at which the breaker contacts separate and at which the resulting reaction takes place in the induction coil.

This instant at which ignition is effected is an important point in the cycle of operations through which the internal combustion engine passes. It is at some time during the compression stroke, or at the end of this stroke, that the gas must be ignited. The exact instant at which the spark occurs depends on several factors but in all cases the object sought is that the entire charge will be fully aflame and at the point of greatest pressure when the piston has reached the top of its stroke and is ready to descend on the power stroke.

The ignition flame starts in the gas immediately surrounding the spark and finally reaches the farthest

points of the combustion space in the cylinder. During this time of flame travel, the piston of the engine is moving with greater or less rapidity up or down in the cylinder, the piston speed depending on the number of revolutions that the crankshaft is then making in a given length of time. In order that the engine may develop the greatest possible power from the

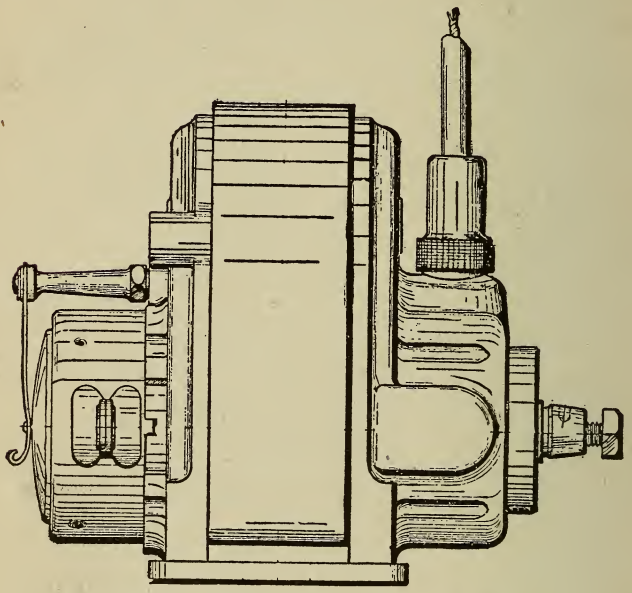

Figure 63.—The C. A. V. Magneto.

amount of fuel being used it is necessary that the gas be ignited at such time as will insure maximum pressure immediately after the piston starts on its down stroke.

In order to cause the electric spark to pass through the inflammable mixture at such time as to produce

complete ignition of the charge when required, a majority of systems provide means for altering this time of breaker action to correspond with engine speed.

THE CONDENSER

It has been explained that the change of magnetism in the core of the coil which takes place upon breaking the primary current causes a flow of current in the secondary winding of the coil and this same change of magnetism produces a flow of current in the primary winding as well. This induced flow caused by breaking the current at the points is of much greater voltage than the primary current itself and tends to continue to flow between the contacts as they open, thus causing an arc or hot spark.

A device called a condenser is incorporated in the ignition apparatus for the purpose of collecting the induced current, preventing its causing a destructive arc at the contacts and also allowing the power of the induced current to be returned to the coil in such a way that the change of magnetism affecting the secondary winding is greatly increased and the resulting current in the secondary circuit is raised in voltage to produce a spark much hotter than would otherwise be secured.

The condenser consists, in the form usually employed, of a number of strips of tin foil separated by insulators such as oiled or paraffined paper or cloth. Mica also is used in some cases as the insulator. Alternate strips of the tin foil are attached to each other so that one-half the total number of strips connects with one terminal of the condenser while the remaining half connects with the other terminal. This

arrangement provides a large surface of an electrical conductor (tin foil) separated by very thin layers of insulating material, which is in this case, called the dielectric.

THE MAGNETO

A magneto is a form of dynamo-electric machine especially adapted for the production of current suitable for ignition but not suited for the production of a current that will charge a storage battery. The current from a magneto is alternating, and periodically changes its direction of flow; while from a dynamo, the flow is direct and does not reverse its travel. The magneto has its fields formed by permanent magnets. Its current of comparatively low voltage is changed to a high tension current by means of an induction coil carried in the magneto.

The type of magneto known as the true high tension carries a secondary winding on the magneto armature together with the primary winding. The primary armature winding then acts as the primary of the combination which is, in effect, an induction coil, and produces changes of magnetism in the common core. These changes induce the high voltage impulses in the fine wire secondary winding.

The principle upon which a magneto of the armature type generates current may be understood by reference to Figure 64. The parts shown at *A* include the horseshoe shaped permanent magnet *M* to whose extremities are attached the extensions *P-P* called pole pieces. The inner faces of these pole pieces are curved and between them rotates the iron core *B* on the magneto drive shaft. On the core is carried a coil of wire *C* and it is in this wire that the current flow is induced.

The coil and its core are parts of the magneto's armature.

With the armature in the position shown at *A* in the illustration the magnetic lines of force from the magnet poles flow from the positive to the negative side,taking the path indicated by the arrows through

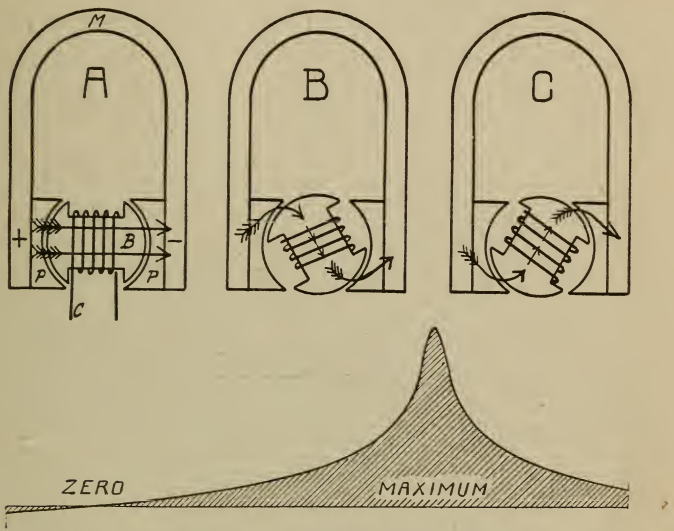

Figure 64.—Rise and Fall of Voltage With Rotation of Magneto Armature Coil.

the center of the coil. As the magneto shaft is rotated, the core and coil finally assume the position shown at *B*. The lines of force still flow through the core, but because of the lessened surface presented to the face of the pole pieces, the flow has become smaller. Further rotation brings the parts to the position shown at *C*. Between *B* and *C*, the flow of magnetism through the coil stopped and again commenced, but

now in the opposite direction through the core and the coil wire. Between these last two points there has been an abrupt change in the intensity of magnetism acting on the coil, in fact a complete reversal has taken place. At the end of a half revolution a second reversal takes place as the core once more assumes a midway position between the pole pieces and for each complete revolution of the armature there are two abrupt changes of magnetic flow through the core and coil. The rise and fall of the voltage is shown by the curve in the lower part of the illustration.

The construction of a typical high tension magneto of the single-cylinder type may be understood by an examination of Figure 65. The beginning of the armature primary circuit is in metallic contact with the armature core, and the end of the armature primary circuit is connected by means of the breaker fastening screw to the insulated contact block supporting the long contact on the breaker. The breaker arm carrying a short platinum contact is mounted on the breaker base, which in turn is electrically connected to the armature core. The primary circuit is completed whenever the two contacts are brought together and interrupted whenever these contacts are separated. The separation of the contacts is controlled by the action of the breaker arm as it bears against the steel cam or segment secured to the inner surface of the breaker housing.

The high tension current is generated in the secondary circuit only when there is an interruption of the primary circuit, the spark being produced at the instant the breaker contacts separate. The armature secondary circuit is a continuation of the armature

primary circuit, the beginning of the secondary being connected to the primary while the end of the secondary is connected to the insulated current collector ring, or slip ring, mounted on the armature just inside the driving shaft end plate of the magneto.

THE DISTRIBUTOR

In the four-cycle engine each cylinder fires once for each two revolutions of the flywheel. A single-

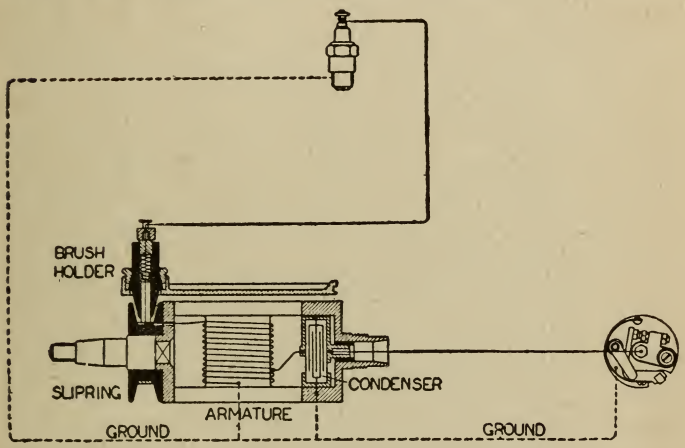

Figure 65.—Low Tension and High Tension Circuits of Single-Cylinder Magneto (Bosch).

cylinder engine would therefore require one spark which would call for one separation of the breaker contacts every second revolution of the flywheel. A two-cylinder engine would require twice as many sparks, or one for each revolution of the flywheel. Four cylinders call for two sparks each flywheel revolution.

All of the sparks produced by the magneto are caused by the action of one pair of breaker contacts

and it will be evident that some means will be necessary to send successive sparks to different cylinders of any engine other than a single-cylinder type. The device which sends the current to the proper cylinder is called the distributor.

The distributor receives the flow of secondary or high tension current from the fine wire winding of the armature coil and directs this flow of current into the wire leading to the spark plug in the cylinder which is then ready to fire, that is, to the cylinder whose piston is at the upper end of its compression stroke and ready to descend on the power stroke.

In the single-cylinder magneto, no separate distributor is required, as the high tension current from the armature secondary circuit is passed by the slip ring to a single brush, which is supported by a brush holder at the side of the shaft end of the magneto. A high tension cable between the brush holder terminal and the spark plug in the cylinder completes the secondary circuit.

Two-cylinder magnetos often use a double ring to which the two ends of the secondary winding are led. High tension current for one of the cylinders is taken from one ring while the other ring supplies the remaining cylinder. Such a construction is shown in Figure 60.

The four-cylinder distributor consists of an insulating cap or head in which are secured the terminals to which spark plug wires attach. Inside of the cap is a revolving member called the rotor which receives the high tension current from the coil, and by moving from point to point around the cap, carries this current to segments or pins which are in electrical connection with the spark plug wires.

The distributor of this type is mounted above the breaker but with both breaker and distributor rotating in the same plane as shown in Figure 66. In this type of equipment the breaker cam has only half the number of lobes as there are cylinders to be fired and the distributor rotates at one-half the breaker speed. The driving connection between the two parts is secured by a gear carrying the distributor rotor meshing with

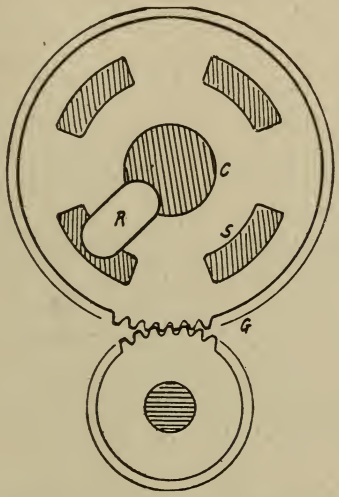

Figure 66.—Distributor Drive for Four-Cylinder Magneto.
C: Central Contact. G: Driving Gears. R: Rotor.
S: Segment Attached to Spark Plug Wire.

a pinion half the size of this gear and mounted on the breaker shaft.

Two distinct types of distributor construction are in use. One type called the wipe contact, provides carbon or metal brushes in the distributor rotor or the cap, or in both rotor and cap, which complete the connection for the high tension current. The other

type, called a jump spark distributor, leaves a minute air gap between the current carrying member of the rotor and the connection for the spark plug cable terminal, the secondary current jumping across this air gap for each discharge of high tension current.

SPARK PLUGS

The spark plug is a device designed to carry the high tension current into the combustion space of the engine and to allow the current to form an arc or spark between two points separated by a definite gap, the heat of this spark causing ignition of the fuel mixture to take place. The spark plug must operate under the difficult conditions of extreme variations in temperature and pressure while at the same time preventing the improper escape of an electric current of thousands of volts pressure.

In its simplest form the spark plug consists of a shell threaded on its outside surface so that it screws into some part of the combustion space wall, and inside of this shell an insulating bushing through which passes a conductor called the central electrode and through which the secondary current enters the combustion space. These parts of the plug are shown in Figure 67.

The distance apart of the points in the spark plug is of great importance in properly firing the mixture. With a magneto as the source of ignition current the spark is comparatively weak at low speeds and becomes stronger and better able to jump the gap as the engine speed and magneto voltage increases.

For average conditions and in the average engine the distance between the electrode ends, or the spark

plug gap, should be between twenty-five and thirty thousandths of an inch. With magneto ignition, low speed missing calls for a smaller gap and high speed missing for a larger gap.

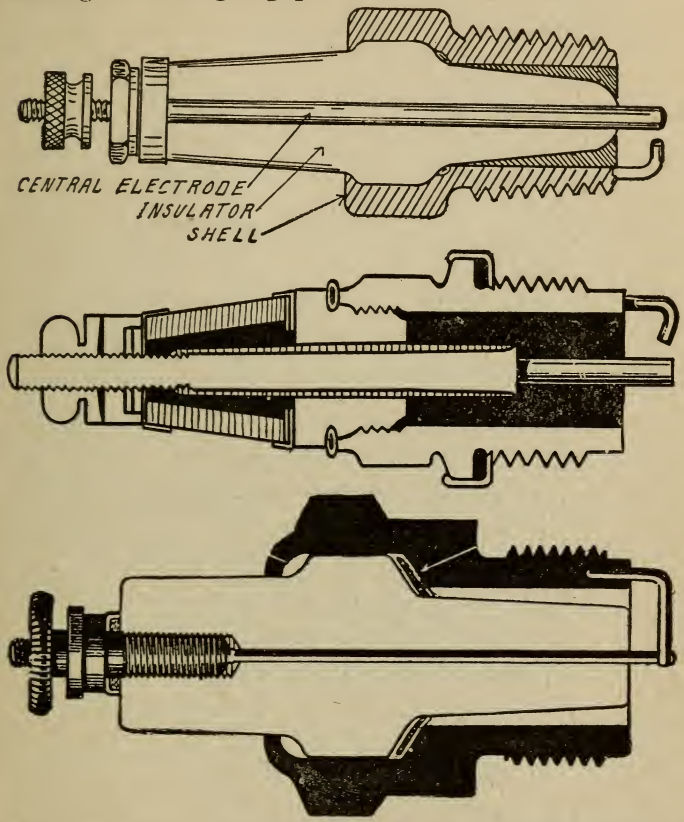

Figure 67.—Top: Parts of a Spark Plug. Center: Section Through Splitdorf Spark Plug With Mica Insulation. Bottom: Section of A. C. One-Piece Spark Plug.

The setting of the spark plug electrodes is an important function which is usually overlooked, with the

result that the magneto is blamed when it is not at fault. The setting of the spark plug electrodes should seldom exceed a gap of .025 of an inch to obtain the best results. Nothing is gained by a larger gap as it only imposes an extra strain on the magneto. This has

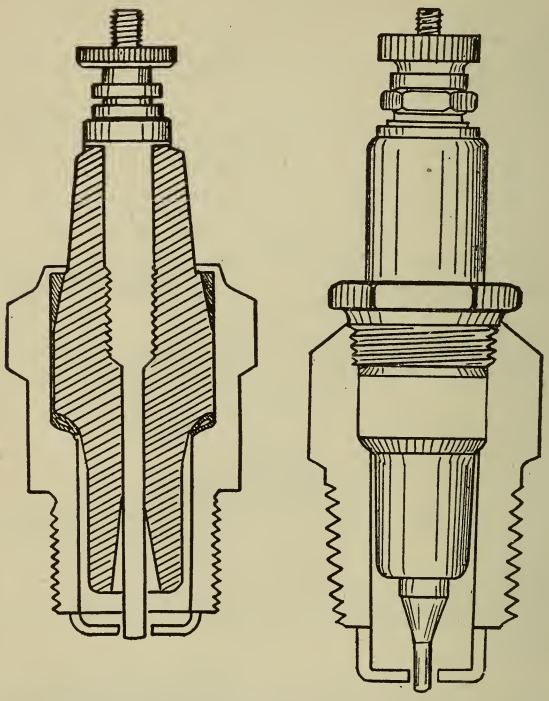

Figure 68.—Left: One-Piece Spark Plug. Right: Two-Piece or Separable Spark Plug.

been demonstrated by practical experience, both in touring and racing. If the engine does not fire evenly in both cylinders and a spark plug is suspected or skips in one cylinder, it is advisable to reverse the plugs, that is, place the suspected plug in the other

cylinder and should it continue to skip, the spark plug should be cleaned or replaced by a new one.

Two-piece plugs may be easily cleaned by removing the bushing and the core from the shell and brushing the core with an old tooth brush dipped in gasoline. When the carbon deposit on the core is very heavy it may be scraped clean with a knife. Sometimes a spark plug is tested by holding it against the cylinder while sparking. This is not proof that the spark plug is in good condition as a plug will often spark in the open air but not when subjected to the compression of the engine.

The ends of the spark plug electrodes should be cleaned from time to time with a piece of emery paper, as it has been found that the gasoline and oil sold in some localities will leave a deposit on the electrodes of the plug. This increases the resistance of the electrodes and will not permit the spark to pass freely from one electrode to the other. While inspecting the plug, the gap should be regulated, bearing in mind that a small gap makes easy starting but that an ordinarily wide gap gives better all-around results.

Should it be necessary to use a mica spark plug that has become badly oil soaked, most of the oil may be removed by means of heat. The core of the plug should be removed and held in the flame of a blow-torch for some length of time, at least until the appearance of burning oil has disappeared.

Spark plugs can be more easily inserted and withdrawn if the threads are covered with graphite or a graphite paste. A cold plug should never be screwed into a hot engine because the contraction of the hot cylinder walls onto the cool plug will make the two parts into practically one piece.

The insulating core through which passes the central electrode may be permanently fastened into the spark plug shell, in which case the plug is of the non-separable or solid type, or else the core may be held in place by means of a packing nut and gaskets so that the center assembly is easily removable for cleaning or replacement. This latter type is called

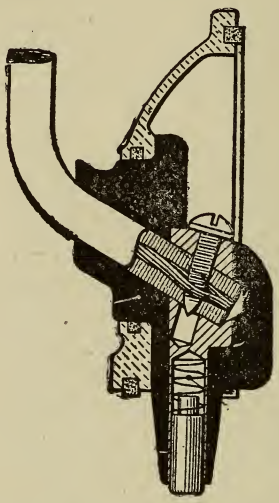

Figure 69.—Spark Plug Wire Attachment on Single-Cylinder Bosch Magneto.

a separable or two-piece plug. Both constructions are shown in Figure 68.

In Figures 69 and 70 are shown methods of attaching the spark plug wires to the magneto and the connection between the end of the wire and the brush that collects high tension current from the armature. Figure 69 shows the entire cover plate of the magneto and shows the carbon brush extending downward to

meet the collector ring. Figure 70 shows a brush holder that attaches at one side of the magneto.

MAGNETO SETTING AND CARE

Magnetos are often driven by means of a flexible direct connected coupling on a shaft intended for the purpose. As the magneto must be driven at a high speed, a coupling of some flexibility is preferable.

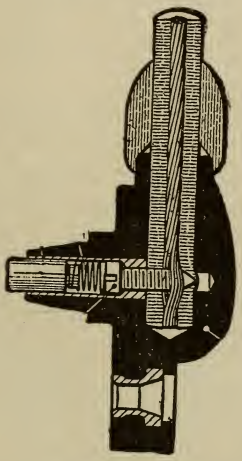

Figure 70.—Spark Plug Wire Attachment on Twin-Cylinder Bosch Magneto.

A small inaccuracy in the lining up of the magneto with the driving shaft will be taken care of by the flexible coupling, whereas with a perfectly rigid coupling, the lineup of the magneto must be absolutely accurate. With the flexible coupling the vibration of the engine will not be as fully transmitted to the armature shaft of the magneto as in case a rigid coupling is used.

Another method of driving the magneto is by means of a gear keyed to the armature shaft. Where this method of driving is employed, great care must be exercised in providing sufficient clearance between the gear on the magneto and the driving gear. If there should be a tight spot between these two gears it will react disadvantageously on the magneto. The third available method is to drive the magneto by means of a chain. Wherever gear or chain drive is used, precautions must be made against oil working into the magneto from the case containing the gears or the chain.

Berling Magnetos.—To set the magneto, the piston in some one cylinder of the engine should be brought to the point on the compression stroke where the extremely advanced spark is desired to occur. The location of this point will vary somewhat in different makes of engines, but in the majority of cases it will be found to be somewhere between 3/8 inch and 3/16 inch before the piston reaches top-center on its compression stroke. This position can be accurately determined by removing either the inlet valve or the spark plug and bearing on the top surface of the piston with a wire or stick. By rocking the engine slowly backward and forward, the exact top-center position of the compression stroke can be determined by watching the highest position of the wire or stick. Now turn the engine backward until the wire or stick drops the desired amount of advance for the engine in question. Next move the timing lever as far as possible in the direction opposite to the direction of rotation of the magneto. With the timing lever in this position, turn the magneto armature in the direction of the rotation until the contacts on the breaker just begin to open.

The gear or coupling which was left loose for this purpose should now be tightened, thus rigidly fixing the relation between the piston of the engine and the magneto armature. With this setting the spark will occur

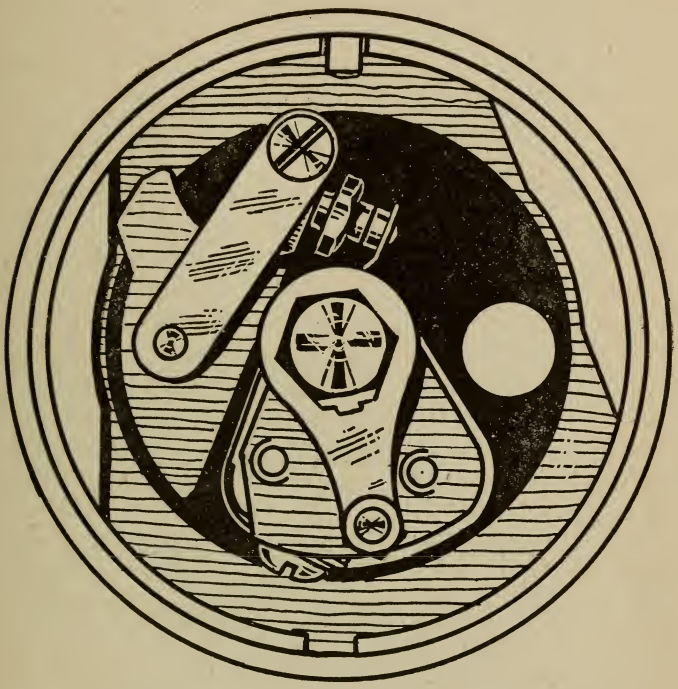

Figure 71.—Breaker Construction of Berling Magneto.

in the front cylinder at the proper time. The breaker is shown in Figure 71.

If the setting of the magneto and its connection to the engine have been carefully made according to these instructions, and the engine nevertheless should not give the maximum power, it is possible that the

amount of extreme advance of the piston has not been correctly chosen and it will be necessary to reset the magneto, using a different amount of advance.

The setting of the magneto on a two-cylinder engine firing at 180 degrees is the same as that for the V type and may be made from either cylinder, care being exercised that the cam corresponding to the terminal attached to the plug in the cylinder being used is correct, otherwise the spark will occur on the exhaust stroke.

The timing range of the magneto is twenty-five degrees, and with the setting as above described the spark may be made to occur several degrees after the piston passes top-center for starting or low speed running.

With the fiber lever in the center of one of the embossed cams, the opening between the contacts should be not less than .016 inch and not more than .020 inch. The gage riveted to the adjusting wrench should barely be able to pass between the contacts when fully open.

The contacts must be smooth and if pitting is in evidence, the surfaces should be smoothed off with a very fine file. When in the closed position the contacts should come into proper relation with each other over their entire surfaces.

When inspecting the breaker, make sure that the ground brush in the back of its base is making good contact with the surface on which it rubs.

There is provided on the cam housing cover a grounding spring and terminal. This terminal should be connected to a simple grounding switch for cutting out the ignition. This is a low tension connection so that it is not necessary to use high-tension cable.

Lubricate the cams in the cam housing and the two rubbing surfaces of the fibre lever with a thin film of vaseline for every fifty hours of actual running. After the magneto has been installed put ten drops of clean light cylinder oil in each oil cup and repeat

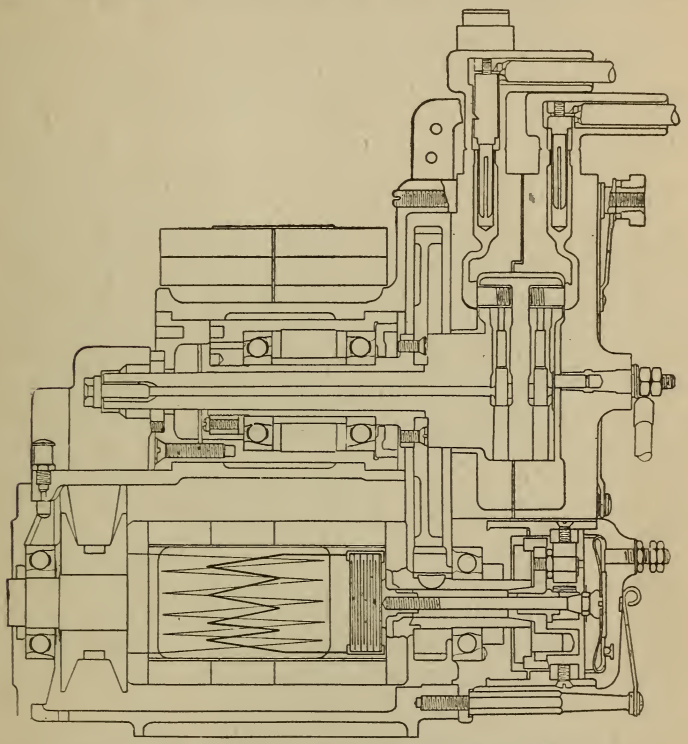

Figure 72.—Section Through Berling Magneto.

this every thousand miles of actual running. Never use oil in the breaker and pay particular attention to prevent oil or other lubricant from reaching the contacts.

Bosch Magnetos.—To time the magneto to the engine, the crankshaft or flywheel is rotated to bring the piston to within one-quarter inch of top dead center on the compression stroke, and is maintained in that position. The magneto is then secured to the engine with the points of the breaker in the act of separating, the breaker housing being fully advanced.

Rotating the housing in the direction opposite rotation, as indicated by an arrow on the oil well cover, gives the advanced position.

The engine may be started and will operate with this timing, but if the engine characteristics are such that full power is not secured, the setting must be changed to bring the spark earlier in the piston stroke.

In timing a magneto on a twin-cylinder engine as shown in Figure 60 the operation is similar. The piston of cylinder number one is brought to within one-quarter inch of top dead center of the compression stroke and maintained in that position. The magneto is then to be secured to the engine with the points in the act of separating, the breaker lever coming into contact with the steel segment bearing the mark *I*, the spark control lever being in full advance position.

When the breaker lever is acted on by segment *I*, the spark that is produced will pass to carbon brush *I;* this carbon brush is to be connected to the spark plug of cylinder number one. Carbon brush *II* is then to be connected to the second cylinder.

If these settings do not develop the desired power output, the magneto is to be advanced slightly in relation to the crankshaft, the spark thus being produced when the piston is more than one-quarter inch from top dead center to the compression stroke. It will be found that in general the spark should occur at a

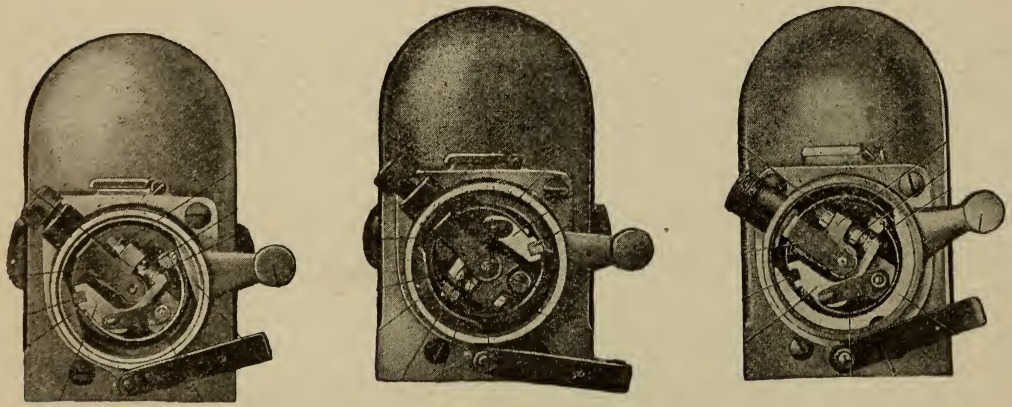

Figure 73.—Right: Breaker of Single-Cylinder Magneto. Center: Breaker of Twin-Cylinder V-Type Magneto. Left: Breaker of Twin-Cylinder Horizontally Opposed Magneto (Bosch).

point in the stroke from one-quarter to five-eighths of an inch from top dead center.

The only care required by the magneto is the oiling of the bearings, each of which should be given not more than four or five drops every five hundred miles. The breaker lever is intended to operate without lubrication. Oil on the points will prevent good contact and will cause sparking and burning as well as an engine miss, therefore, great care should be exercised to prevent the entrance of oil to these parts. The correct gap between the breaker contacts when separated is .014 of an inch.

Dixie Magnetos.—The principle of operation may be understood by reference to Figure 74. The magneto consists, in its principal parts, of a set of magnets, a rotating member, a special field structure carrying the coils, the coil windings, a breaker, and a condenser.

The rotating member, or rotor, consists of two revolving wings *N* and *S*, shown at *1* in the illustration, which are separated by a bronze center piece. These wings are carried by the magneto drive shaft and revolve between the poles of the magnets, one rotor revolving adjacent to the North pole while the other revolves close to the South pole. Because each rotor always revolves close to its own pole of the magnets it always maintains the same magnetic polarity, one always being positive while the other is always negative.

Again viewing a section of the magneto and looking across the magnets as in *2*, *3* and *4* of Figure 74, in place of through the arch as in *1*, it will be seen that the rotor is enclosed by the lower ends of an arched field structure, on the upper part of which are placed

the coil windings. As the rotor revolves it causes the magnetic lines of force to be changed about so that the magnetism flows back and forth through the field structure and the core of the windings, first in one direction, then in the other, according to the position of the rotor in relation to the poles of the field structure.

Still referring to Figure 74 it will be seen that, by

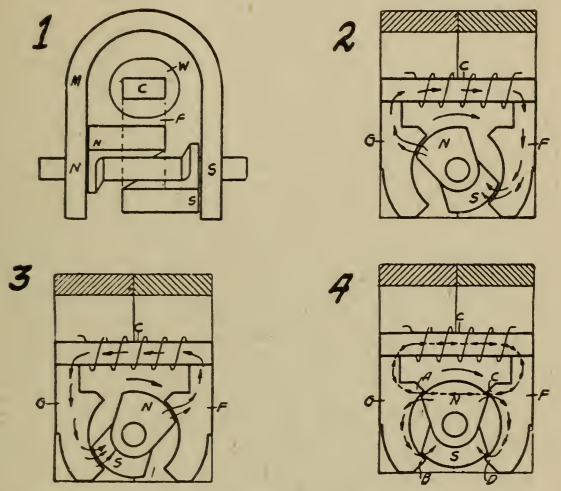

Figure 74.—Operating Principle of the Dixie Magneto.

rotating the wings very close to the ends of the magnets, they are in effect the rotating poles of the magnet. At right angles to the rotating pole pieces or wings is the field structure consisting of laminated pole pieces *F* and *G* carrying across their top the windings *W*. When *N* is opposite *G* the lines of force flow from one pole *N* of the magnet to *G* and through the core *C* and *F* as shown in *2* of the illustration.

As shown at *3*, the pole *N* has moved over to *F* and the direction in which the lines of force flow is reversed through the core and windings, now passing from *F* through *C* and *G*. At *4* in the illustration the rotating pieces occupy a position midway between the two foregoing so that the field pieces *F* and *G* are magnetically short circuited and all the lines of force are removed from the core *C*.

Facilities for oiling are provided by an oil hole on the side of the instrument and ten drops of light oil every five hundred miles are sufficient. Before oiling, it is advisable to clean the oil hole of dust and grit. The breaker lever bearing should be lubricated with a few drops of light oil applied with a tooth pick every five hundred miles. The proper distance between the contact points when separated should be .020 inch.

Whenever the wires leading from the magneto are taken off make sure that they are properly replaced. On a magneto of right hand rotation as shown by the arrow on the back plate cap, the terminal marked No. 1 always leads to the cylinder which fires first and which is usually the rear cylinder.

Should it become necessary to clean the collector spool, remove the three screws holding the brush holder support and take the brush holder off, being careful not to damage the rubber gasket or ring.

The collector spool may be cleaned with a piece of cloth dipped in gasoline and wrapped around the eraser end of a lead pencil. This is inserted in the hole of the housing, at the same time rotating the magneto by turning the motor over a few times to insure thorough cleaning.

The carbon brushes in the brush holders should be free and project about one-quarter of an inch from

the end of the holder. Do not pull out the carbon brushes.

For timing a single-cylinder engine, rotate the crankshaft or flywheel so as to bring the piston to the upper dead center of the compression stroke. With the timing lever fully retarded, the points of the breaker should be about to separate. For engines of the twin-cylinder type, rotate the crankshaft so as to bring the piston of No. 1 cylinder, which is usually the rear one (the first in direction of rotation) to the upper dead center of the compression stroke. With the timing lever in the full retard position, the points of the breaker should be about to separate when the fibre bumper of the breaker bar begins to ride on the nose of the cam marked No. 1. Some engines may require an earlier setting to obtain the best results.

Simms Magneto.—To time the magneto, crank until cylinder number one is on top dead center with valves closed (beginning of working stroke, with connecting rod swung over on downward stroke side). Remove the breaker cover and distributor cap. Turn the magneto armature in the direction it must run until the contacts are just opening with the timing lever in the fully retarded position (the retarded position is obtained by pushing the timing lever down in the same direction as the magneto armature rotates). The distributor carbon brush must at the same time be in a position to touch the distributor segment serving cylinder number one. The driving gear or coupling should then be securely tightened on the magneto armature driving shaft, using the key in the keyway provided in the shaft. The magneto can now be coupled to the engine, care being taken not to change the foregoing adjustments.

It must always be remembered that the distributor brush rotates in the opposite direction to the armature, and that number two terminal on the distributor does not necessarily lead to number two cylinder, but to the cylinder firing after that to which number one wire is led. The same applies to number three and number four terminals and cylinders.

Any advance or retard desired in addition to that to be obtained by the variation of the timing lever must be secured on the engine alone by advancing or retarding the engine timing gears, but in no case should the setting of the magneto distributor or internal armature gears be changed, as these have a certain fixed relation to each other. Different settings of these two gears will seriously impair the efficiency of the magneto.

The magneto should be oiled every two weeks or one thousand miles run with four or five drops of light machine (not cylinder) oil in each of the oil holes which are located over the armature driving shaft and near the top of the distributor. The breaker should never be oiled; it may cause serious difficulty if oil is allowed to remain on it.

The points should be set so as to open on each cam about one sixty-fourth of an inch, or the thickness of the gage on the wrench furnished. These points should be kept clean and free from oil, and should make even contact with one another over their entire surface. The breaker lever should pivot freely in the bushing. The breaker should be inspected occasionally and freed of dirt and oil. Only if it should become absolutely necessary should the platinum points be filed, and then only with a very fine flat file and by using great care.

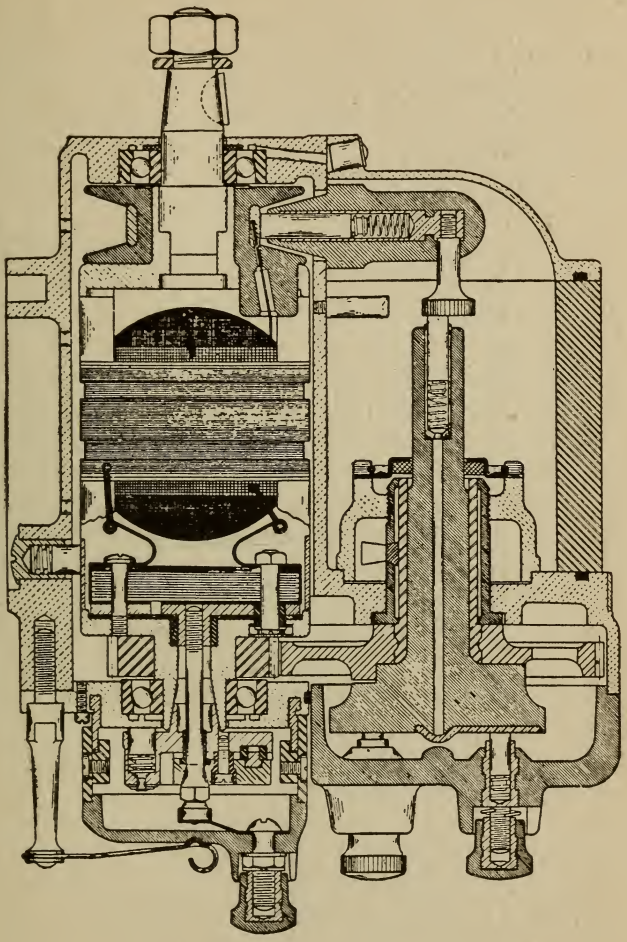

Figure 75.—Construction of Simms Magneto.

MAGNETO AND IGNITION TROUBLES

It is almost invariably the case that ignition trouble is due to a defective or dirty spark plug. It should be remembered that as the spark will have a tendency to burn the metal of the electrodes, the gap will gradually increase in size through use. The spark plug should therefore be examined occasionally for assurance that the gap is not too great.

The magneto breaker lever should move on its pivot with sufficient freedom and the points should be so adjusted that they are separated. When the adjustment is made, great care should be taken to set the lock nut firmly in position. If the lock nut backs off it may cause serious injury to the parts.

It is very rarely that difficulty is encountered with the magneto and suspicion should not be placed on the magneto until all other sources of trouble have been investigated. If the magneto is suspected, the first thing to do is to determine if it will deliver a spark. To determine this, disconnect one of the high-tension leads from a spark plug in one of the cylinders and place it so that there is approximately one-sixteenth of an inch between the terminal and the cylinder frame.

Open the pet cocks on the other cylinders to prevent the engine from firing and crank the engine until the piston is approaching the end of the compression stroke in the cylinder from which the cable has been removed. Set the magneto in the retarded position and rapidly rock the engine over the top-center position, observing closely if a spark occurs between the end of the high-tension cable and the frame.

If no spark is observed, then the trouble is in the

magneto. If a spark is observed the spark plugs should be investigated. To do this, disconnect the cables and remove the spark plugs. Then reconnect the cables to the plugs and place them so that the shells of the plugs are in metallic connection with the frame of the engine. Then crank the engine, thus revolving the magneto armature, and see if a spark is produced at the spark gaps of the plugs.

If the magneto and spark plugs are in good condition and the engine does not run satisfactorily, the setting should be verified according to instructions previously given and, if necessary, readjusted to give correct timing.

When attaching a magneto to a V type twin-cylinder engine it should be remembered that some of these engines have their cylinders set at an angle of 42°, others at 45°, and still others have an opening as great as 90°. It is not possible to use a 42° magneto on a 45° engine nor is it possible to make any other combination unless the units are designed to operate together. It is also important to know that the magneto is designed for the direction of rotation in which it will be driven.

Among the commonly encountered magneto troubles are the following: The breaker contacts may be dirty, their gap may be incorrect, the contacts may be loose, or the breaker arm may be sticking. The contacts may sometimes be badly out of line with each other or one or more parts of the breaker may have worked loose. Some of the small brushes about the armature or breaker may have become broken or may be sticking in their holders.

The distributor should be examined to see that it is not wet or dirty. The collector ring should be

kept clean and the safety spark cap should be free from accumulations of oil and dirt.

If the magneto has been taken apart it may be found that the magnets have been replaced in the wrong position, that is, with part of the positive poles on one side and part of them on the opposite side of the armature. Careless handling of the magnets may have caused them to loose their strength. If the magneto drive is badly worn or loose or if the armature bearings in the magneto are loose, it will be difficult if not impossible to secure a satisfactory spark.

The spark plugs will give trouble if the insulator is dirty either inside of the shell or on the part exposed outside the engine. The insulator may be broken if of porcelain or oil-soaked if of mica, and either type may be loose in the shell. The points of the plug between which the spark is supposed to pass may be touching each other or may be short circuited by oil or carbon. These points may have been burned away until the gap is too great or they may have worked loose, either in the core or in the shell. A plug should be of the correct length for the engine with which it is used, that is, it should not be so short that it will be pocketed and reached only by dead gases, neither should it be so long that there is danger of the plug end being struck by the valves or piston of the engine.

The wiring should be examined to see that it is not short circuited or accidentally grounded by moisture, oil, or dirt. The insulation should be examined to see that it is not broken or chaffed especially at points of support. It may sometimes be found that the wire strands have become broken underneath the insulation.

As a general rule, the spark should be carried as

far advanced as possible while running, this advance being just short of the point at which knocking is caused. The spark advance should generally be in proportion to the speed of the engine regardless of the power being developed. The engine should never be operated for any length of time with the spark retarded. When starting the engine with magneto ignition it may sometimes be necessary to advance the ignition almost all the way but with battery ignition a one-third to one-half advance will be sufficient if the timing is correct.

A great many magnetos are driven by means of a chain and it is important that this chain be kept at the correct tension. Should the tension be too great there will be a grinding noise while the engine is slowing down with the compression release open. If the chain is too loose it will rattle. Unless the magneto drive chain is enclosed and automatically lubricated it will be treated in the same way as a driving chain, that is, cleaned and lubricated with a graphite grease preparation.

CHAPTER VI

DYNAMO LIGHTING AND IGNITION

THE STORAGE BATTERY

A storage battery for motor cycle use is made up of three storage cells. Each cell contains two kinds of plates, positive and negative, made from compounds of lead and immersed in a liquid composed of sulphuric acid and water. A chemical action takes place between the plates and the liquid and the result of this chemical action is a flow of electricity through wires that are attached to the battery terminals. The battery does not store, and does not contain electricity, but is capable of generating a flow of current because of the action that takes place in the battery.

In order to bring the elements of the battery into such condition that they will cause a flow of current, it is first necessary to send a flow of electricity through the battery. The energy of this current being sent through the battery is consumed in making one series of chemical changes and when outside circuits are connected to the battery, these changes take place in a reverse order and most of the energy absorbed from the flow of charging current is given back into the circuit to do useful work. The parts of a motor cycle battery may be seen in Figure 76.

The plates are made up of a metal framework called the "grid," and a paste called the active material.

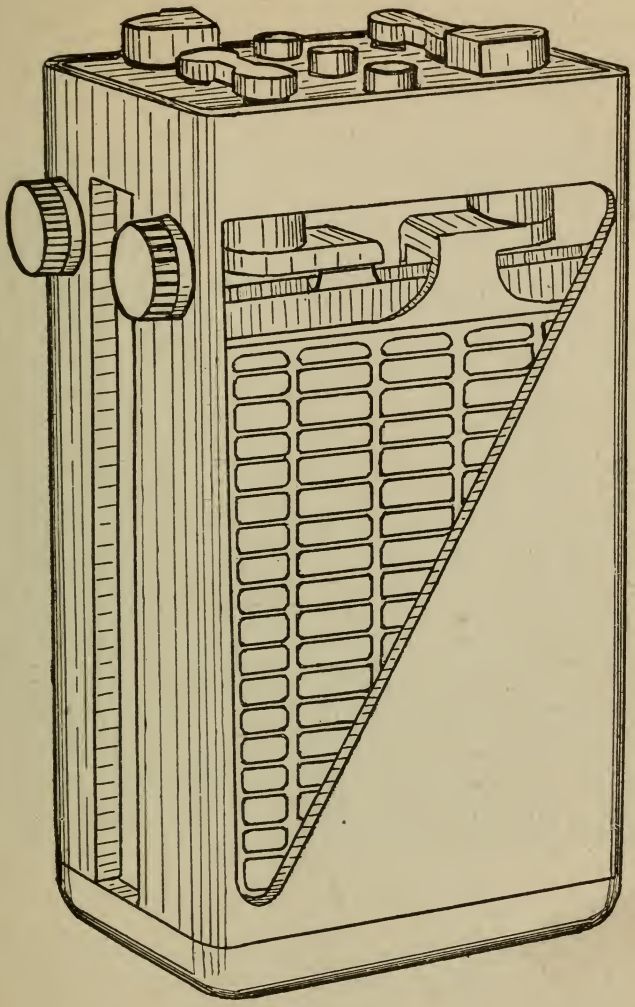

Figure 76.—Parts of the Wico Motor Cycle Battery.

is used to fill the spaces in the grid. Adjacent plates are prevented from touching each other by the use of insulators placed between them. The jar in which the plates, insulators and liquid are carried is made

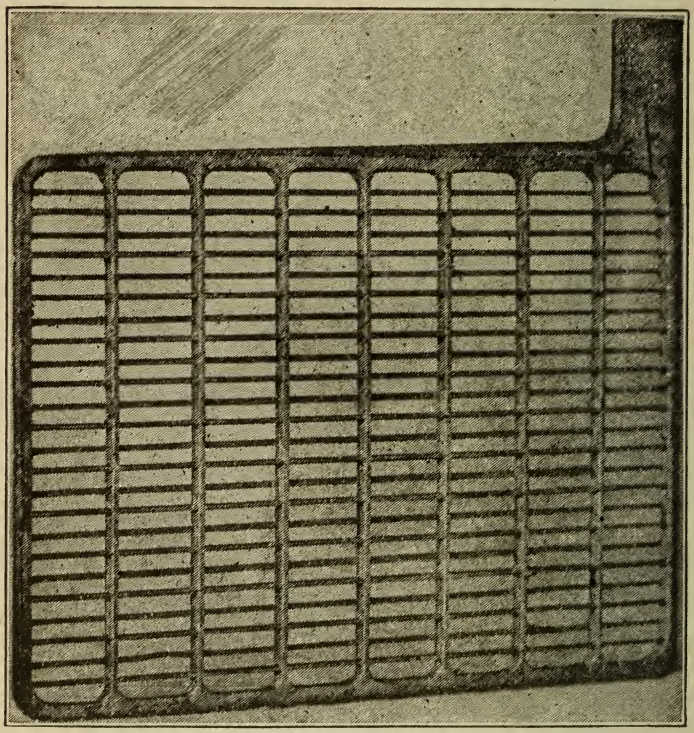

Figure 77.—Construction of Battery Grid.

from insulating material that resists the action of the acid in the liquid. A grid is shown in Figure 77.

The active material is made from lead oxides combined with other materials to give hardness and tough-

ness and to make the plates porous so that the liquid can act on the material. The spaces between the bars of the grid are filled with this paste. The cell contains one more negative than positive plates and they are placed alternately so that both outside plates are negaive. This arrangement is shown in Figure 78.

All the positive plates are joined together and all

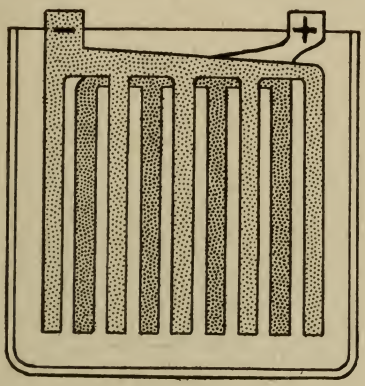

Figure 78.—Positive and Negative Plates Alternating in a Battery Cell.

of the negatives are similarly fastened together with connecting straps. The positive connecting strap is attached to the positive terminal of the cell, while the negative strap is fastened to the negative terminal. The groups thus formed, together with an insulator, are shown in Figure 79.

A flow of electric current sent through the cells causes a change in the material of the plates and the positives turn to peroxide of lead while the negatives turn to sponge lead. When the material in the grids

has been completely transformed the battery is charged.

The voltage obtained from one cell does not depend on the size or weight of the cell. The normal voltage

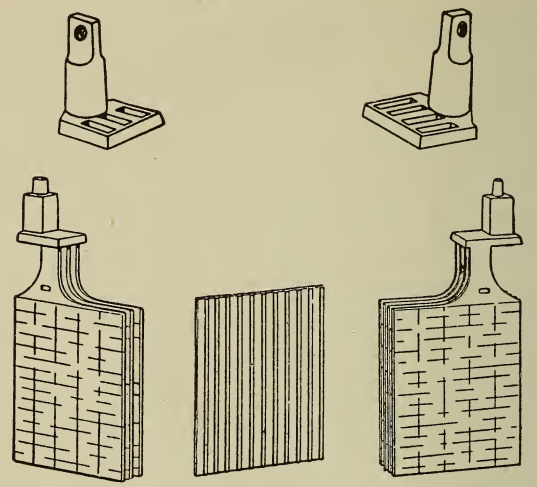

Figure 79.—Positive and Negative Groups, Connecting Straps, and Insulator.

under operating conditions is two for the cell, although this voltage varies slightly with the state of charge of the battery. When the material in the plates has been completely changed to peroxide of lead and lead sponge and the cell is still being charged, the voltage may be as high as 2.5, while with the battery discharged to a point at which no more current should be drawn, this voltage will fall to between 1.7 and 1.8 for the cell.

In making ordinary calculations it is customary to consider each cell as causing a pressure of two

volts so that a three-cell battery is called a six-volt battery. The current that a cell will give is measured in ampere-hours or in watt-hours, generally by the former. An ampere-hour is the total quantity of current that passes in one hour if the flow is continuous at a rate of one ampere. An ampere-hour will also pass if a flow of one-half ampere is maintained for two hours. The number of ampere-hours is found by multiplying the number of amperes flowing by the time in hours. Batteries are generally rated according to their ampere-hour capacity, this capacity being based on discharging the battery in eight hours. A battery rated as a twenty ampere-hour battery would give a flow of one ampere for twenty hours or, theoretically, a flow of twenty amperes for one hour. This latter flow could not be secured in practice because of the action that would take place in the cells under such a heavy discharge rate.

As previously stated, a charged cell has had its positive plates changed to peroxide of lead and its negatives to sponge lead. When the battery is connected to the wiring circuits so that it lights the lamps, an action immediately begins to take place between the plates and the acid electrolyte. A part of the sulphuric acid in the liquid begins to combine with the lead in the plates to form lead sulphate and the plate material is gradually turned to this sulphate. The percentage of water in the electrolyte is increased because of the combining of part of the oxygen and the sulphur of the acid with the lead of the plates, leaving the hydrogen and oxygen in the form of water, which is a combination of these two gases. The plates thus change slowly to lead sulphate, while the liquid becomes more nearly pure water. When the dis-

charge has continued until the normal output of the battery has been secured, it will be necessary to send a charging current through the cells in a direction the reverse of the flow that takes place during discharge.

With the charging current flowing, the sulphate of the plates combines with part of the hydrogen and oxygen in the liquid to form sulphuric acid. The positive plate then becomes peroxide of lead and the negative is left as sponge lead. This transformation continues until the sulphate is completely reduced and the battery is then said to be charged.

The greatest care that is necessary in allowing a battery to discharge is to see that it does not do so to such a point that the voltage becomes abnormally low. Under no conditions should discharge be continued when the voltage is 1.7 per cell, and if the current flow from the battery is carried past this point serious damage will result.

From the explanation of the action during charge and discharge, it will be seen that the proportion of acid in the electrolyte will give an indication whether the battery is properly charged or nearly discharged. The acid is much heavier than water, and as the proportion of acid in the liquid becomes greater, the weight of the electrolyte becomes greater. Therefore, the heavier the electrolyte, the more nearly charged the battery is known to be.

To find the condition of the battery by testing the liquid, a hydrometer shown in Figure 80 is used. The hydrometer is a glass tube having a hollow bulb and a weight at one end and a thin tube with a numbered scale at the other end. When this instrument is allowed to float in the liquid from the battery cells,

the point on the scale to which it sinks indicates the weight of the liquid, because, of course, the hydrometer will not sink so deep into the heavy liquid with a large proportion of acid as it will into the liquid

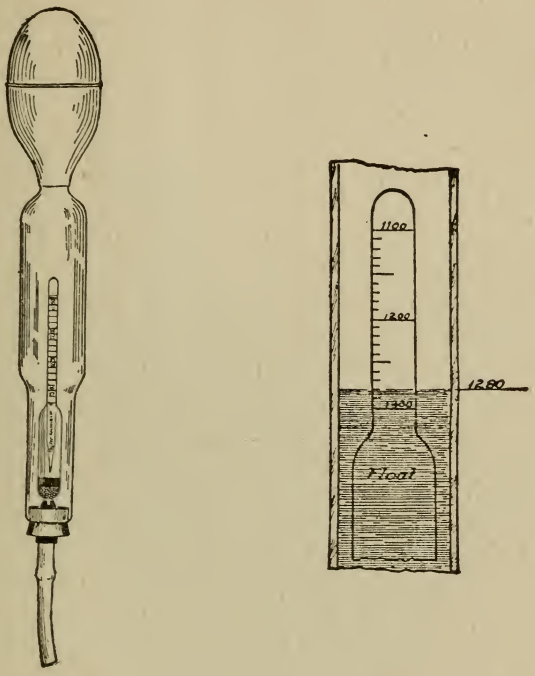

Figure 80.—Left: Hydrometer Syringe. Right: Hydrometer Scale.

when almost all water. The scale is graduated according to the weight of liquids, known as specific gravity, which is their weight compared to that of pure water.

On the stem of the hydrometer appear numbers from 1.100 near the top, to 1.300 near the bottom.

With the battery fully charged the hydrometer will sink only to the point between 1.250 and 1.300; but with a discharged battery whose electrolyte is mostly water the hydrometer will sink almost to the 1.100 mark. Different degrees of charge are indicated by the hydrometer's sinking to points on the scale between the 1.100 and the 1.300 mark. The point indicated at the surface of the liquid is the specific gravity of the electrolyte.

The hydrometer is carried in a tube with a nozzle at its lower end that may be inserted into the cells, and with a bulb at the upper end so that some of the electrolyte may be drawn from each of the cells for purposes of test.

In the top of each cell of every battery will be seen a small plug. This plug may be unscrewed or released from its lock and will leave an opening exposed that passes into the interior of the cell and through which the electrolyte may be seen. The hydrometer syringe may be inserted into the cell, and when the bulb is squeezed and allowed to expand, some of the liquid will be drawn up into the tube and the hydrometer will float in this liquid. After all pressure has been released from the bulb the specific gravity of that liquid may be noted on the hydrometer scale at the point where the instrument rises above the surface of the electrolyte. The gravity should then be noted and the liquid carefully returned to the same cell from which it was drawn.

If this gravity is between 1.250 and 1.310, the cell is well charged. If the gravity is between 1.200 and 1.250, the cell is at least half, but not fully, charged. Gravity between 1.150 and 1.200 indicates that the cell is nearly discharged while the gravity of 1.150

or below means that the cell is discharged to a point at which no further discharge should be allowed.

If the battery is in good condition, the gravity will

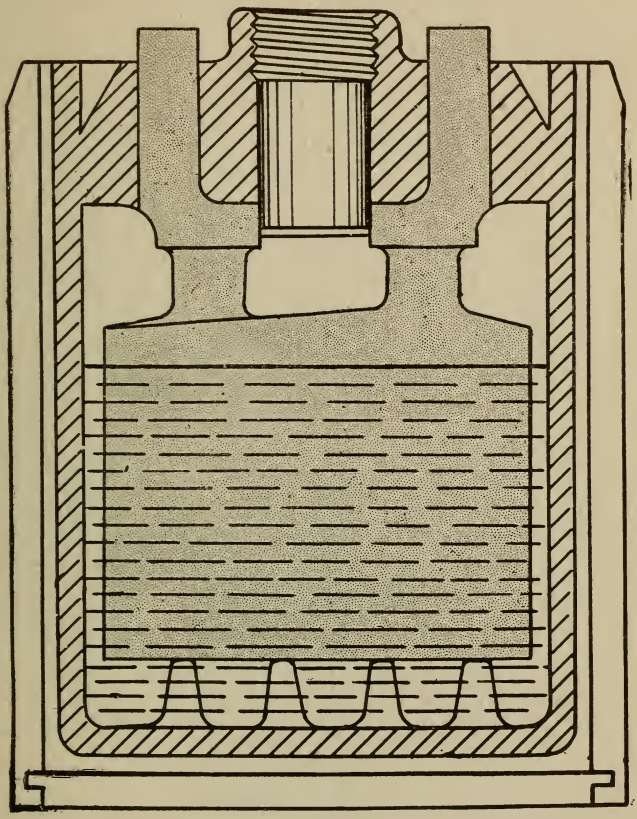

Figure 81.—Low Level of Liquid in a Battery.

be within twenty-five points of the same in all cells. If there is a greater difference it usually indicates trouble in the cell or cells which are low.

Battery Care.—It is essential that the storage battery have certain attention at regular intervals. The most important item in the care of a battery is that of adding pure water to each cell at least once each week during warm weather and at least every second week in cold weather. The water is added through the holes left with the vent plugs removed and may be easily handled by using the hydrometer syringe. A sufficient quantity of water should be placed in each cell to bring the surface of the liquid from one-quarter to three-eighths of an inch above the tops of the plates. The water used for this purpose must be distilled. Tap water or water that has been kept in metal containers must never be used. Except when some of the electrolyte has been spilled from one of the cells, nothing but pure water should ever be added.

The specific gravity of each cell of the battery should be taken at regular intervals and if the whole battery is getting lower the fault should be looked for without delay. If one cell becomes lower, but the others remain normal, trouble in that cell is indicated. Care should be used when testing not to spill electrolyte on top of the battery, as it will cause corrosion at the terminals and partial short-circuiting of the cells. If it is found that one cell always takes more water than others, it is probable that the jar for that cell has become broken.

At the time of testing or adding water to the battery, the terminals should be carefully examined for looseness or breakage, either at the connecting bars between the cells or at screwed or tapered connectors. No copper wires should ever be attached at the lead battery posts, as they will soon be eaten away by

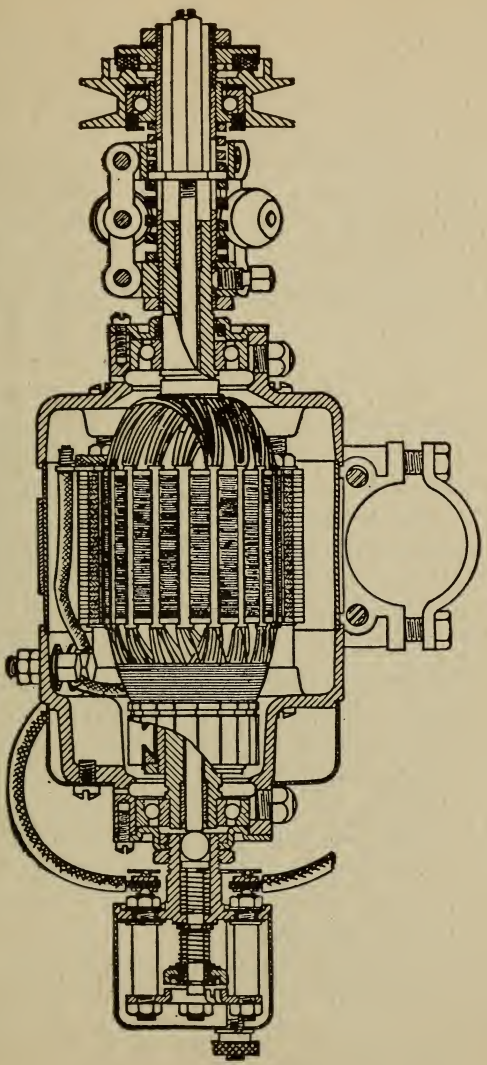

Figure 82.—Lighting Dynamo Construction (A. B. C.).

the action of the acid. Should the connections be found covered with corrosion or verdigris, they should be washed with ammonia water, and in any case should be covered with a coat of vaseline to prevent such action by the acid.

The battery must be firmly secured so that movement from the motion of the cycle is impossible. If the battery case is wet or if the inside of the battery box is wet, the moisture should be wiped away with a cloth slightly moistened with ammonia water.

THE DYNAMO

The dynamo consists of a revolving armature operating in connection with a stationary field. The rotation of the armature generates a flow of electric current in the armature, and the current passes out of the dynamo to the battery and other electrical parts.

The most common form of armature is built by mounting on a shaft a sufficient number of soft iron disks to make a cylinder. This part is called the armature core. Running lengthwise of the core are a number of grooves or slots, these slots being of sufficient width and depth to allow a quantity of insulated wire to be wound on the core and in the slots The coils formed by this wire are called the armature windings, and it is in these windings that the current flow is first generated. One form of dynamo is shown in Figure 82.

Various forms are adopted for the field magnet, the shape depending on the size and mounting that will be required for the particular machine being designed. The ends of the magnet are curved to bring

them close to the armature and the cylindrical passage between them in which the armature rotates is called the armature tunnel.

Should the magnets be formed with four or six ends, as is often the case, the ends are placed so that they form pairs on opposite sides of the armature and are directly across from each other as in Figure 83.

The magnets that produce the field are made from soft iron, and the soft iron, called the magnet core, is

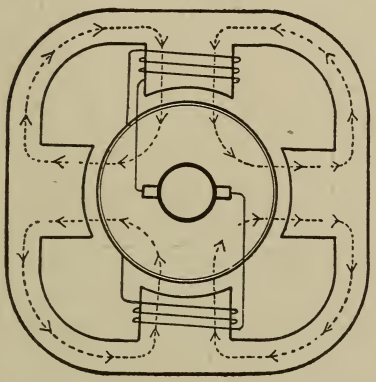

Figure 83.—Flow of Field Magnetism in Four-Pole Dynamo.

surrounded with a coil of insulated wire. When a flow of current passes through this wire, the soft iron becomes an electro-magnet. The coil of wire around the magnet core is called the field winding, and the current that passes through this winding to make the core magnetic is secured by taking a part of the current generated in the armature.

As the armature rotates, the current caused to flow through the armature coil travels in one direction

while the armature makes a half revolution, and then, on the next half revolution, the current is caused to pass in the opposite direction. Such current is not suitable for battery charging purposes, and in order to change this alternating current into a flow that always travels in one direction, the commutator is used. The current having a continuous direction of travel is called direct current, and is the only form suitable for battery charging.

The commutator consists of a number of copper bars arranged in a circle around one end of the armature shaft and fastened to the shaft so that they turn with it. These bars are insulated from each other. Each pair of copper bars is fastened to an armature coil that rests in one pair of slots and the other bars are fastened to the other coils of wire that form the armature.

Brushes, made from some material that carries electricity, are placed so that they rest against the surface of the commutator bars. The brushes are therefore in contact with the two ends of the armature coil. Any flow of electric current generated in the armature winding will pass into these brushes.

Now, bearing in mind the fact that the current reverses each half revolution, and also the fact that the commutator bar in contact with one brush at one position will have changed to the other brush when a half revolution has been made, it will be seen that the current will always be given to the brushes in the same direction as in Figure 84.

From the brushes, wires and connections lead to the battery, lamps and other current-consuming devices, and in most cases to the field magnet windings also. The method of leading part of the generated

current around the field magnets is one of the important considerations in dynamo design.

With increase of dynamo speed, the pressure, measured in volts, and the flow, measured in amperes, both increase in proportion. Unchecked increase in voltage and amperage would result in damage to the electrical parts. In order to prevent such damage various methods have been adopted for controlling the dynamo output.

The voltage of the dynamo must be greater than the voltage of the battery in order that current may flow from dynamo to battery. Just as long as the dynamo voltage remains above that of the battery,

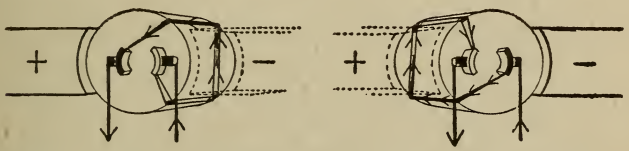

Figure 84.—Action of Commutator in Maintaining Uni-Directional Flow From Armature.

the flow will continue and the battery will receive a charge. When, however, the dynamo voltage falls below that of the battery, as it will when the dynamo is idle or running at very low speed, then the battery pressure or voltage will be greater than that of the dynamo, and if the two units remain connected through the wiring there will be a reverse flow from battery to dynamo. This reverse flow, if allowed to continue, will rapidly withdraw the current from the battery. To prevent such a useless and damaging battery discharge, the dynamo is disconnected from the battery when the dynamo voltage is too low to cause a flow of current to the battery. This is accom-

plished by an automatic switch acting to disconnect the dynamo and battery when the dynamo voltage falls below a certain limit and to establish the connection again when the voltage rises to a point that allows of battery charging. This switch is called a reverse current cut-out, or simply a cut-out.

The dynamo armature is driven from the engine so that its speed increases directly in proportion to increase of engine speed. The dynamo voltage would therefore naturally rise continuously from the lowest to the highest speeds. With the dynamo operating at a variable speed some method of output control is used to decrease the field strength with increase of speed so that the weakened field counteracts the more rapid rotation of the armature and the dynamo voltage is held within certain desired limits. Most motor cycle dynamos are regulated by what is known as the third brush system in which there is gradual increase of voltage until a maximum is reached at some critical speed, followed by a falling off in voltage as the speed becomes still greater.

Regulation.—The voltage between a brush of a two-pole dynamo and a point on the commutator away from this brush depends on the distance of the point from the brush and becomes greater as the distance increases. If one end of the shunt field winding be connected to one brush and the other end of the winding lead to a brush that is not directly opposite the first one, the difference in voltage acting to send current through the shunt field will not be as great as if the field were connected between brushes directly opposite. The brush that carries one end of the winding is generally made movable and the output of the dynamo may be increased or decreased by moving

the brush away from or toward the stationary brush.

At low speeds the flow of magnetic lines of force between the poles of the field magnet is practically straight across, and because of this direction of the lines of force through the armature, the coils which are at any instant in connection with the brushes cut through the greatest possible number of lines of force, and therefore the greatest difference in voltage will be between the commutator points being touched by the main brushes.

With increase of armature speed, the lines of force do not continue to pass straight across but are carried part way around in the direction of rotation by

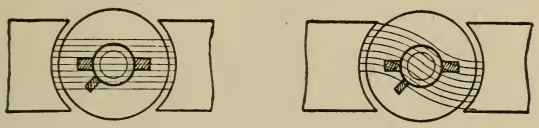

Figure 85.—Distortion of Lines of Force Used in Third Brush Regulation.

the core of the armature as shown in Figure 85. With the magnetism flowing in this distorted path, the armature coils that are at any time attached to the regulating brush through the commutator are not cutting as many lines of force as at lower speeds, and the voltage difference is less than with the lines of force passing straight across. This reduction of voltage causes the amperage passing through the shunt field to decrease, and even with the rise in armature speed, the output does not increase proportionately because of the weakened field. With further increase of armature speed the path of the lines of force is still further distorted and the field current drops to such an amperage that the total output of the dynamo

becomes less and less through the highest speeds of rotation.

DYNAMO CARE

In order that the brushes may make a good contact the commutator surface must be smooth and perfectly cylindrical. Should the surface become dirty, scratched, rough or pitted it must be restored to good condition at once if the dynamo is to be maintained in good condition. Should an examination show it to be blackened or dirty it may be cleaned by holding a soft cloth slightly moistened with gasoline against the commutator surface while the dynamo is being driven by the engine at the lowest possible speed.

If the surface of the commutator is rough or slightly scratched and pitted it may be dressed smooth with sandpaper. Emery cloth or emery paper should never be used because emery is an electrical conductor and will short circuit the commutator bars. Before using the sandpaper the commutator should be cleaned as described and the holders and brushes should be so supported that they do not touch the commutator surface. The engine should be run at the lowest possible speed so that the commutator is revolved. A strip of "000" sandpaper should then be cut just as wide as the commutator surface and this strip of paper should be placed over the end of a thin stick of equal width. By holding this paper against the surface of the revolving commutator slight scratches or pitting may be removed.

After the surface is even and bright, the engine should be stopped and every trace of copper dust and sand should be removed from the interior of the

dynamo, either by wiping out with a cloth moistened with kerosene or by blowing out with air under pressure.

The electrical resistance between brush and commutator depends on how well the brush end fits the commutator surface. For this reason the brush ends should be properly fitted. This operation is performed as follows:

A strip of "000" sandpaper should be cut so that it is at least as wide as, and preferably a little wider than, the end of the brush to be handled. With the dynamo idle, the brush should be drawn away from the surface of the commutator so that the strip of

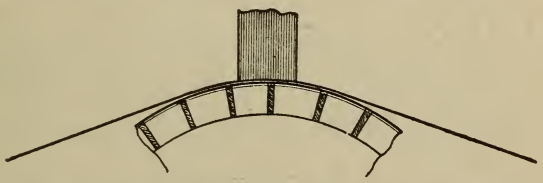

Figure 86.—Fitting Brush End With Sandpaper.

paper may be drawn between the brush end and the commutator with the sand side toward the brush as in Figure 86. The paper should then be drawn back and forth under the brush end and should be held so that it follows the surface and curve of the commutator while passing under the brush. After all roughness and unevenness have been removed from the brush, the end should be carefully wiped with a clean soft cloth. All particles of dust should be removed from the interior of the dynamo with a cloth moistened with kerosene or by blowing them out with air. Each brush should be dressed in this way, even though only one seemed to need the treatment. Great care

should be used in dressing the ends of the regulating brushes and they should always be dressed after moving them to a new position.

REMY EQUIPMENT

Among the earlier models made by the Remy Elec-

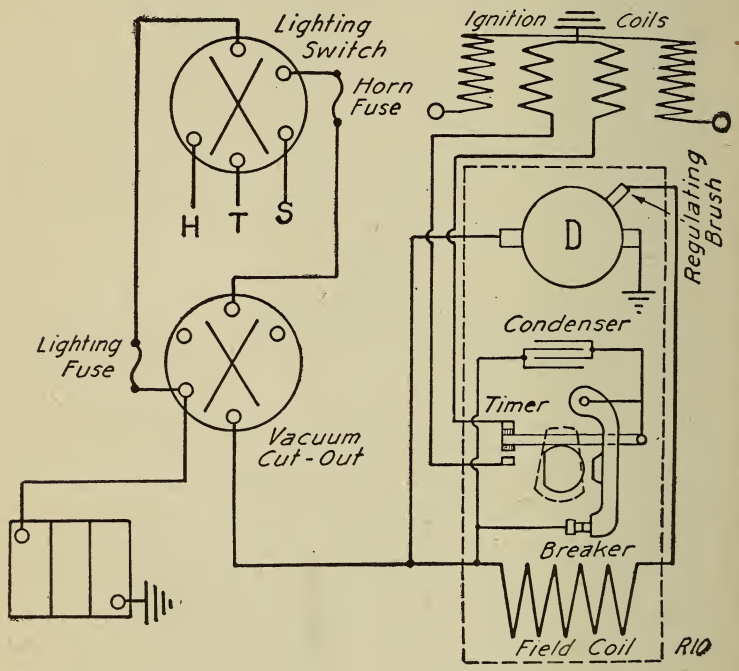

Figure 87.—Wiring Diagram of Remy Ignition Dynamo.

tric Company, was an ignition dynamo of which a large number are still in use. A complete wiring diagram of this equipment is shown in Figure 87. Of the letters at the lighting switch, *H* indicates the head lamp wire; *T* the tail lamp; and *S* the dimmer lamp.

The dynamo contains a single field coil of the shunt wound type, two main brushes and one regulating brush. The outfit is of the six-volt type and the dynamo delivers a maximum current of four and a half amperes.

The cut-out is of a peculiar type, being operated by vacuum from the engine inlet. The construction is shown in Figure 88. The vacuum created in the inlet pipe when the engine is started acts upon the cut-out and draws the contacts together. This makes a connection between the battery and dynamo which is maintained until the engine stops running.

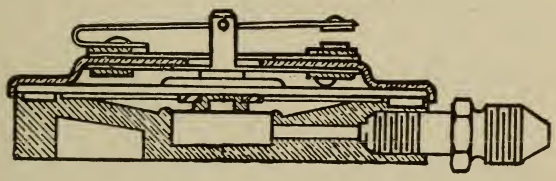

Figure 88.—Construction of Remy Vacuum Cut-Out.

The ignition unit is carried underneath the dynamo as shown in the wiring diagram. The two ignition coils are carried on top of the electrical unit. Details of the ignition breaker are shown in the Figure 89. The breaker consists of a pair of contacts whose operation determines the time of sparking and within the same mechanism is carried a set of metal contacts made up of upper and lower members between which moves an arm carrying a central contact. This serves to send ignition current to either one or the other of the two coils, depending on which cylinder is to be fired. The appearance of the cut-out and lighting switch is shown in Figure 90.

A later model of Remy equipment includes a shunt wound dynamo having two field coils, two main brushes and one regulating brush. A complete wiring diagram is shown in Figure 91. This equipment is

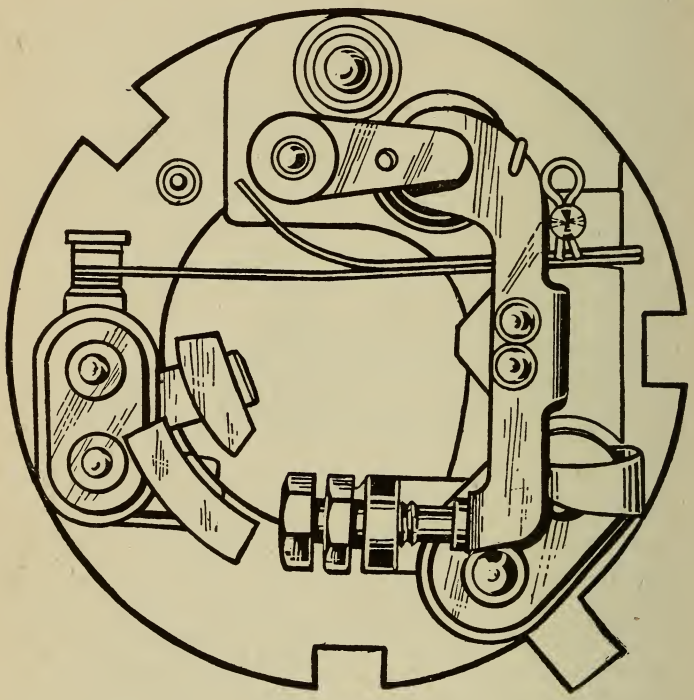

Figure 89.—Ignition Breaker Used With Remy Ignition

of the six-volt type and gives a maximum output of four amperes.

The cut-out is of the centrifugal type and its appearance on the end of the dynamo is shown in Figure 92. In the illustration, *1* indicates a fastening for the regulating brush and *2* indicates the brush itself.

A type of battery ignition mechanism for motor cycles that is very similar to the generally used automobile type of equipment is shown in Figure 93. This unit includes a breaker whose contacts are shown at *9* and which is operated by the cam *8* striking the

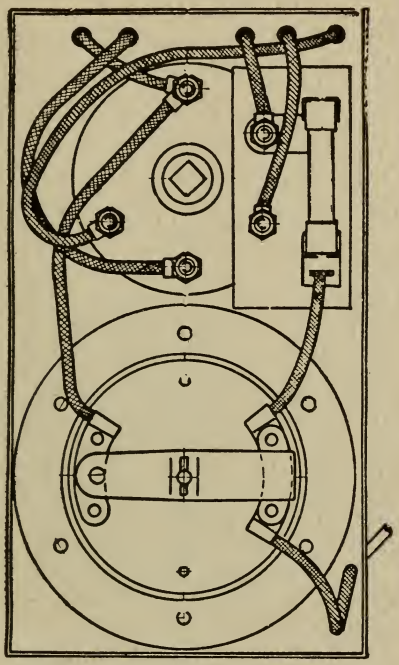

Figure 90.—Position of Cut-Out and Lighting Switch on Remy Ignition Dynamo.

bumper *7*. The contacts are provided with an adjustment at *10* which is locked by the jam nut *11*. Above the breaker is carried the distributor whose rotating member *5* is fitted with a spring contact *4* which bears

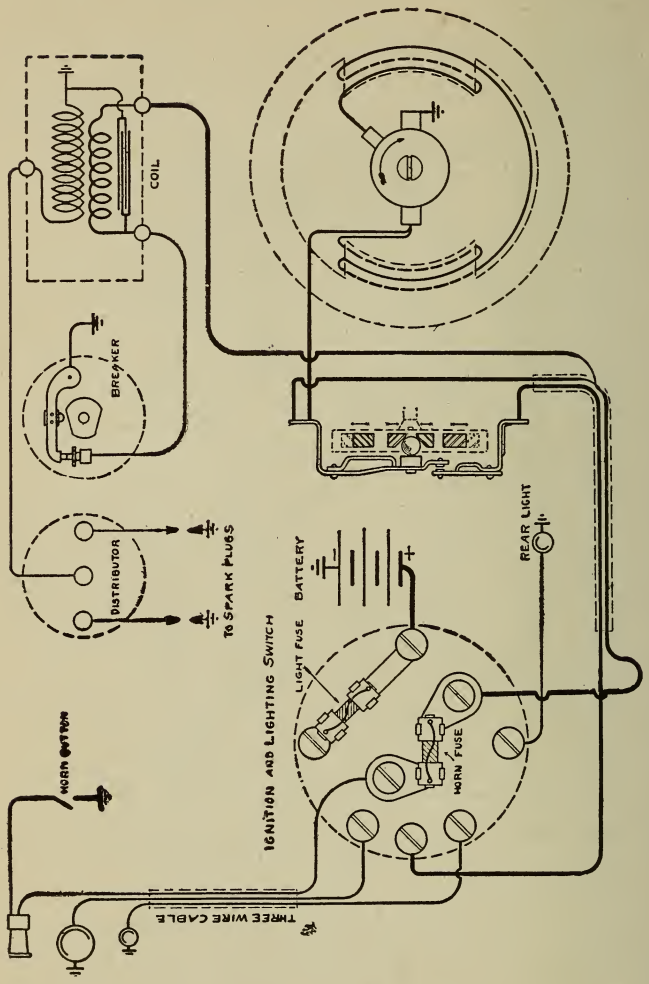

Figure 91.—Wiring Diagram of Remy Lighting and Ignition System, Using Centrifugal Cut-out on Dynamo.

against contact *14* and carries high tension current through wire *15* from the ignition coil *16*. With the device in action, high tension current from rotor *5* passes to the segments *2* from which wires lead to the

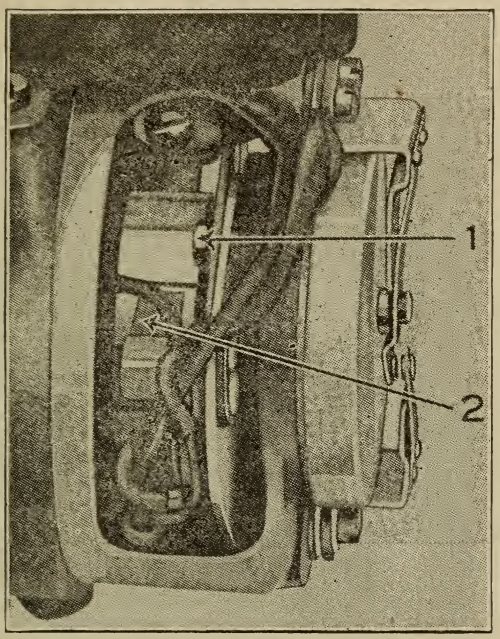

Figure 92.—Commutator End of Remy Dynamo Showing Centrifugal Cut-Out Contacts at the Right. The Regulating Brush Screw Is Shown at 1 and the Regulating Brush at 2.

spark plugs. Primary current between the breaker and the coil is carried throught wire *12*. The distributor cap *3* is held in proper position by the lug *1*, engaging the recess *6* while the spring *13* serves to lock the entire assembly.

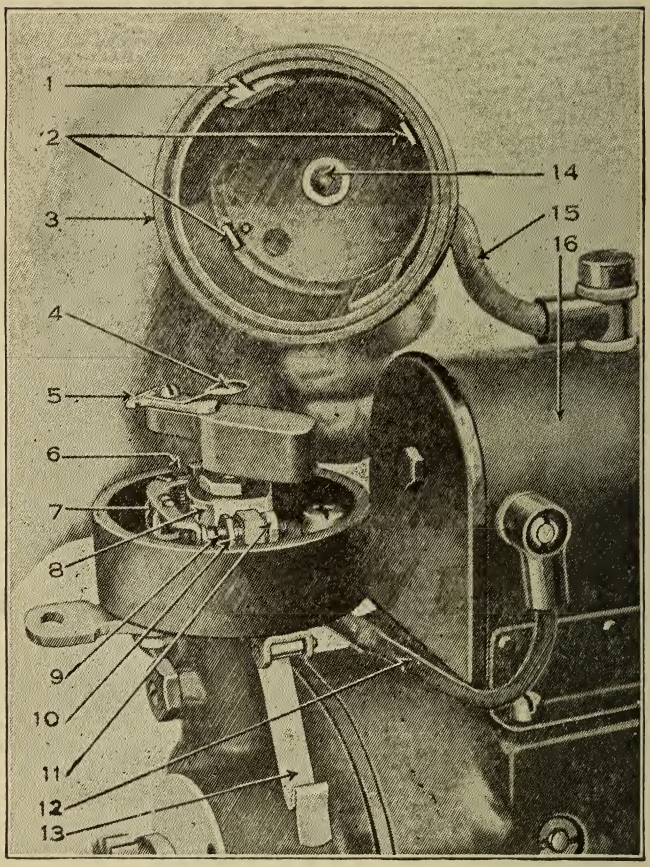

Figure 93.—Remy Battery Ignition System.

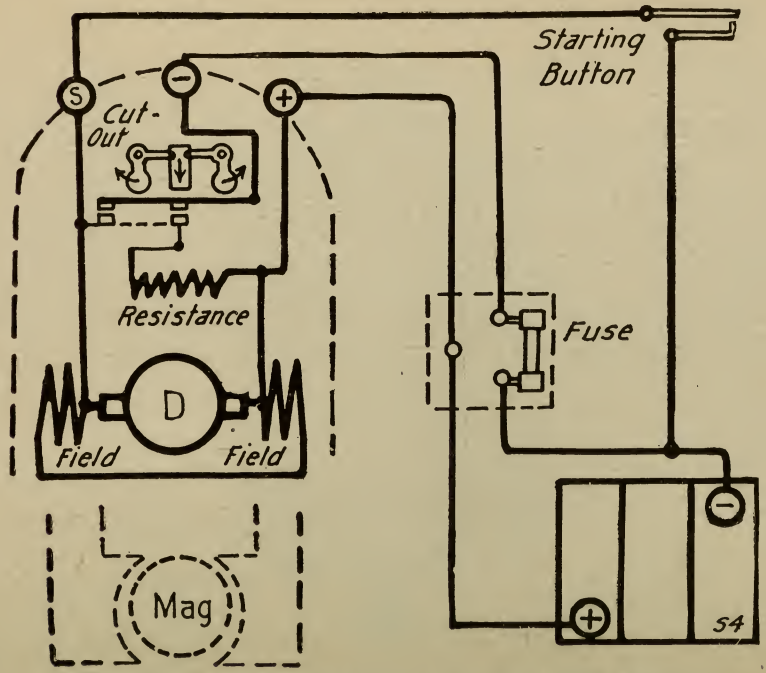

Figure 94.—Wiring Diagram of Splitdorf Mag-Dynamo.

SPLITDORF EQUIPMENT

One of the first units made by the Splitdorf Electrical Company was known as the Mag-dynamo. This outfit consisted of a high tension magneto above which was carried a shunt wound dynamo having two field coils and two brushes. The equipment was of the six-volt type with a maximum output of three amperes.

This Mag-dynamo includes a centrifugally operated controlling device having two sets of contacts as shown

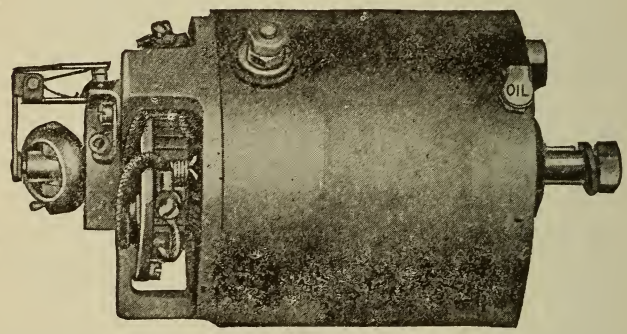

Figure 95.—Appearance of Centrifugal Cut-Out on Splitdorf Dynamo.

in the wiring diagram Figure 94. With the driving shaft in motion, the controller weights force the central plunger in the direction indicated by the arrow. This movement causes the left-hand pair of contacts to close and these serve as a cut-out, connecting the dynamo with the battery. With an increase of dynamo speed the central pair of contacts is closed and this action reduces the field strength and thus controls the output. A starting button is provided whose closing causes the dynamo to act as a motor and, by ener-

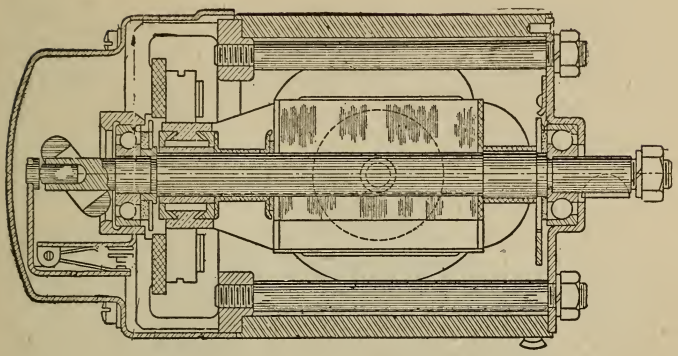

Figure 96.—Construction of Splitdorf Dynamo Having Centrifugal Cut-Out.

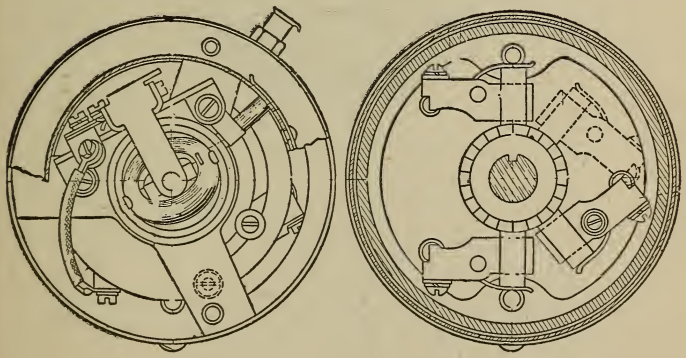

Figure 97.—End Views of Splitdorf Motor Cycle Dynamo.

gizing the fields with storage battery current, a hot spark is produced for starting.

A later type of separate dynamo made by the Splitdorf Electrical Company is shown in Figure 95. This unit is of the shunt wound type having two field coils, two main brushes and one regulating brush. It is of

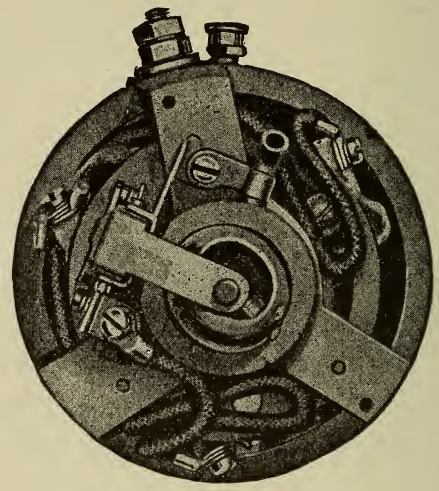

Figure 98.—Centrifugal Cut-Out on Splitdorf Dynamo.

the six-volt type and gives a maximum current of four and a half amperes. Details of the construction are shown in Figures 96 and 97.

The cut-out, shown in Figure 98, is of the centrifugal type operated by a ring weight type of governor carried on the commutator end of the dynamo. The complete wiring connections are shown in Figure 99.

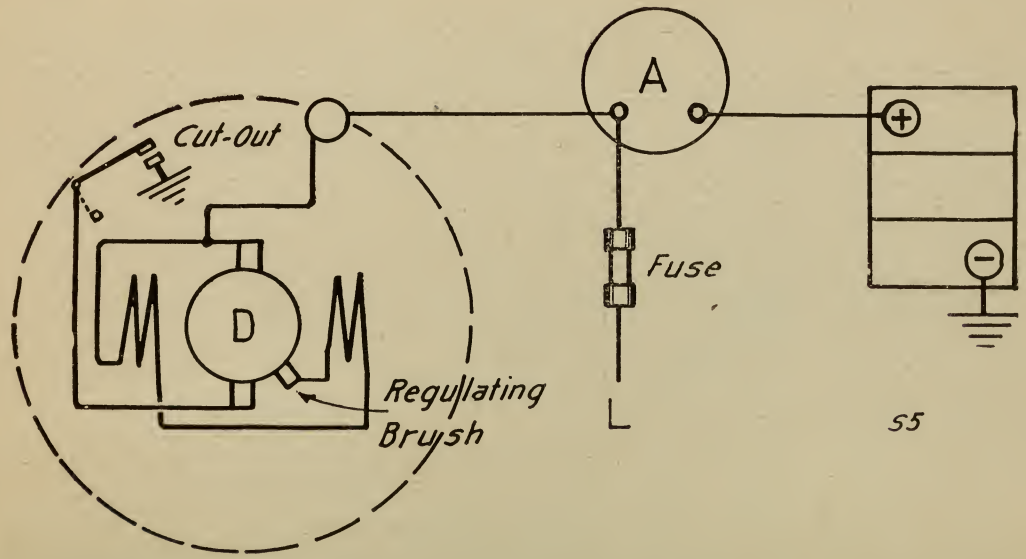

Figure 99.—Wiring Diagram of Splitdorf Dynamo Having Centrifugal Cut-out.

CHAPTER VII

DRIVING PARTS

The driving or transmission system of the motor cycle includes a clutch which allows the engine either to run free from the road wheel or to be connected with that wheel, also a gear-set or transmission proper which provides for various ratios of speed between the engine and the road wheel. The clutch and transmission are, as a rule, combined into one unit.

Between the transmission and the rear wheel, power is carried by chains, gears, shafts, or belts, or else by some combination of these methods. Two parts which would properly be classed as controls are, for convenience, included in the transmission system, these two being the kick starter and the brakes.

The Clutch.—Motor cycle clutches consist of two sets of disks or plates, one set being attached to the engine and the other to the drive. For operating the motor cycle these two sets of disks are held in contact with each other by one or more springs as shown in Figure 100.

The clutch may be located outside of the transmission as shown in Figure 101 and in such a construction the plates are oftentimes designed to operate dry and without any lubrication between their contact surfaces. In other cases, as shown in Figue 102, the clutch is carried inside of the transmission housing and it then operates in the same bath of oil that serves

to lubricate the transmission. The clutch may also be a separate unit from the transmission but may still be lubricated, sometimes being enclosed with the driving gears as shown in Figure 103.

When the clutch springs are allowed to expand and press the disks together, the clutch is said to be

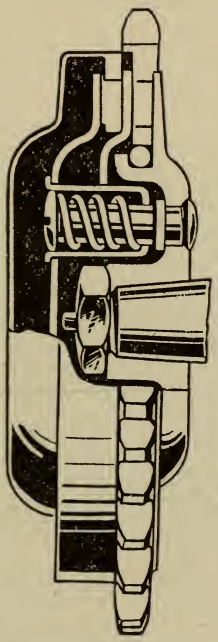

Figure 100.—Three Plate Clutch Carried in Sprocket (Triumph).

engaged and the power of the engine is carried through it to the transmission or to the driving parts. When the clutch springs are compressed, their tension is removed from the disks, the disks are allowed to separate and the engine allowed to run free from

the driving parts. The clutch is then said to be disengaged and this disengagement is accomplished either by means of a foot pedal, by a hand lever or by a combination of pedal and lever.

The clutch control allows the rider to keep the engine running with the motor cycle standing still and then, by slowly engaging the clutch, to pick up the

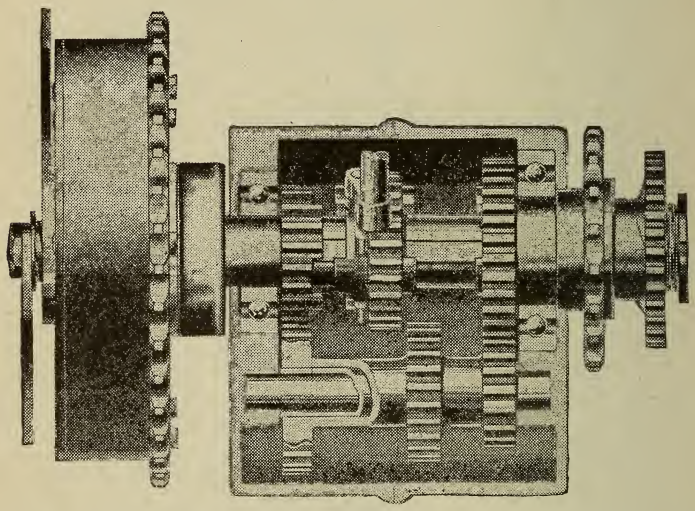

Figure 101.—Clutch Carried in Housing Outside of Gear-Set (Excelsior).

load and start the machine in motion. The clutch may be used as a cushion for the power impulses by holding it slightly disengaged so that the partial slipping allows a smooth drive. If the clutch is properly adjusted this slipping will be provided for and the same adjustment will often allow the rider to increase the pressure on the disks in case of an exceedingly

hard pull. The detailed construction of a typical multiple disk clutch is shown in Figure 104. In this particular example the spring pressure is controlled by turning the screw shown at the extreme left in the center.

In some designs the clutch is actuated by a series of small coiled springs as shown in Figure 105, while

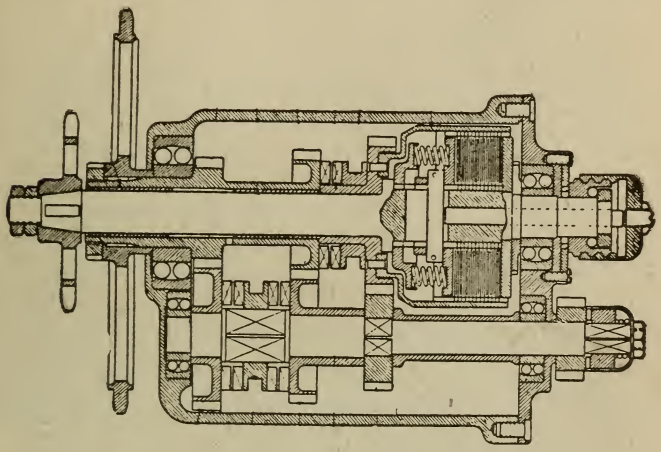

Figure 102.—Clutch Carried Inside of Gear-Set Housing (B. S. A.).

in other cases pressure is applied by one comparatively large spring as shown toward the left in Figue 106.

Clutch Adjustment.—If a clutch does not release or does not engage properly the trouble is more often due to faults in the control connections than to an incorrect tension of the clutch springs. It is necessary, with the clutch in the fully engaged position, that there still remain some free movement of the operating pedal or lever for otherwise a part of the

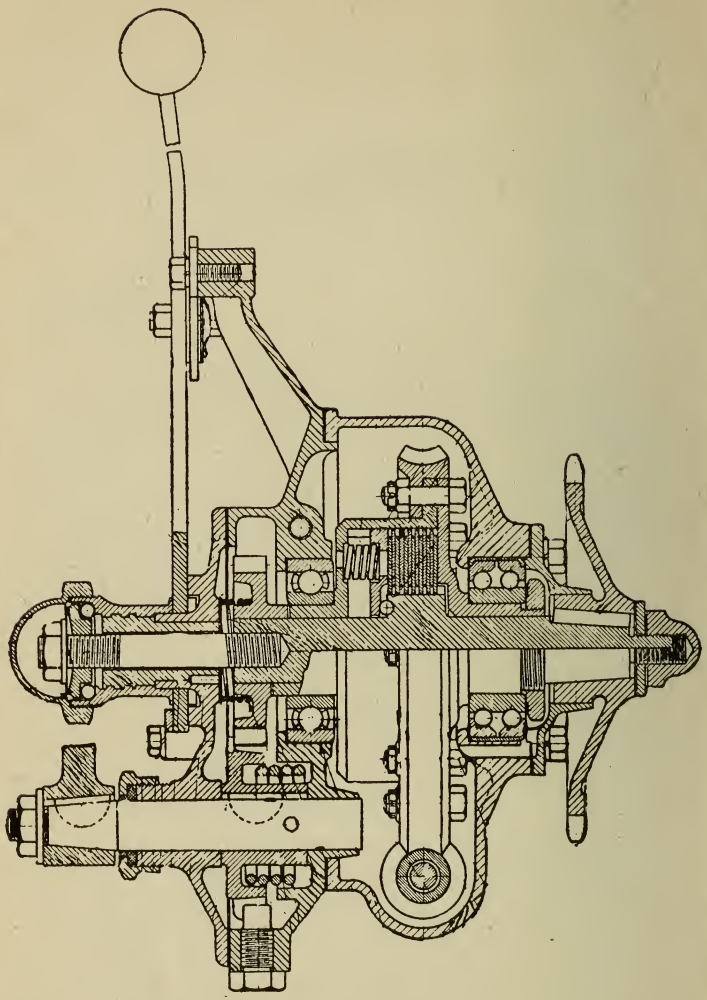

Figure 103.—Clutch Carried Inside of Worm Gear (Cleveland).

spring pressure will be carried by the operating parts and this lost pressure will not be available for holding the disks together. A typical arrangement of connections between clutch and transmission parts and the control pedal and lever is shown in Figue 107.

If it has been found that the controls have the nec-

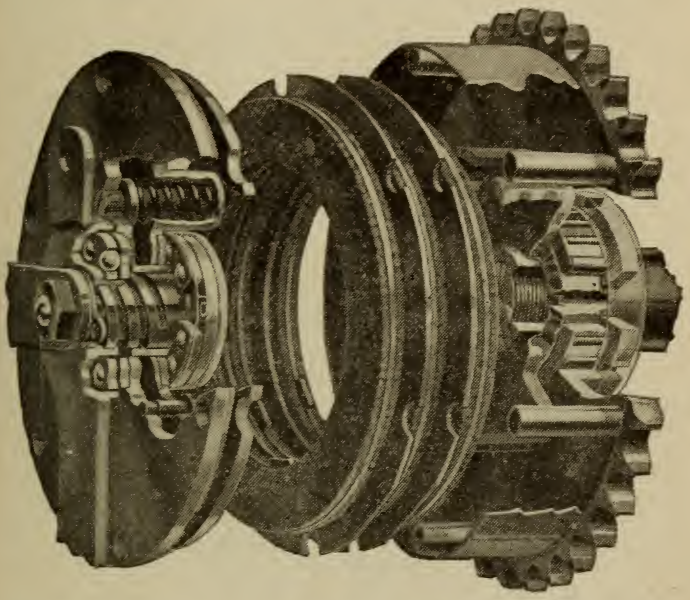

Figure 104.—Construction of Multiple Disc Clutch with Release Screw (Excelsior).

essary free movement when the clutch is fully engaged and if the disks still fail to hold, it may be necessary to adjust the tension of the springs. However, this adjustment should not be made until it has been made sure that the disks are clean and in good condition.

Using the Clutch.—With the usual form of clutch

control in which this member is operated both by a foot pedal and by a hand lever, the clutch will engage only to an extent determined by the position of the hand lever, this being true even though the foot pedal be entirely released. The position of the hand lever

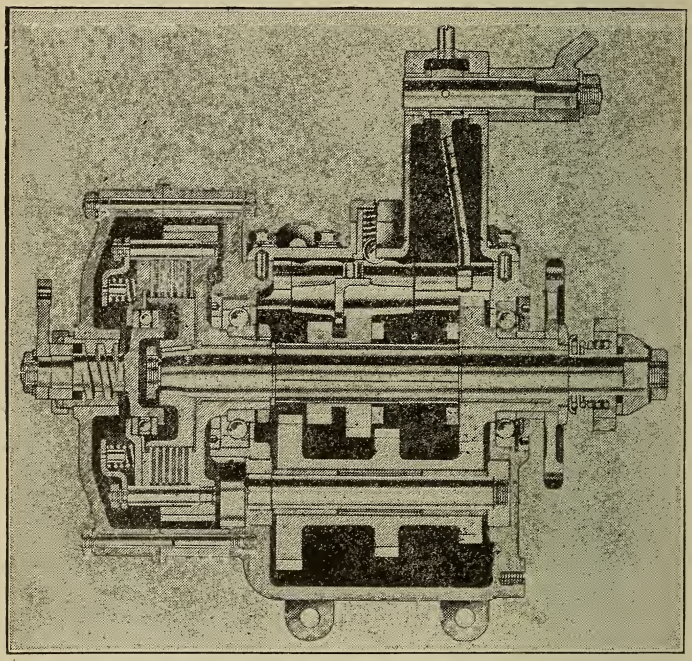

Figure 105.—Multiple Disc Clutch on End of Transmission Housing (Indian).

determines the amount of clutch spring tension that can act upon the disks, and the use of the foot pedal will have no effect on the amount of this tension. The foot pedal is used during the operations of starting, stopping and slowing-up. Because the two controls

are adapted for different uses it is best that the rider should become thoroughly familiar with the use of both lever and pedal.

A smooth drive can be obtained by setting the clutch lever in such a position that the disks are allowed to absorb the shocks which result from the power impulses of the engine. Such use of the clutch will render it comparatively easy to drive slowly through traffic. It might be mentioned that choking of the engine will be avoided while the motor cycle is running at a low rate of speed for some distance if the clutch is frequently released and the engine is speeded up for a few seconds while it is released.

According to the practice followed in driving an automobile, the engine speed is decreased by closing the throttle as soon as the clutch is disengaged and is allowed to remain thus while the transmission gears are being shifted. Theoretically this would also apply to the motor cycle, but in actual practice it will usually be found that the gears are changed so quickly after disengaging the clutch that closing of the throttle will be unnecessary for the engine has no time in which to race.

Clutch Troubles.—Incorrect operation of the clutch may be in either of two ways, dragging or slipping. Either of these troubles may be due to a wrong adjustment of the operating connections or to a wrong adjustment of the spring tension. A dragging clutch may also be caused by disks that are improperly fitted or that have become warped. A slipping clutch will result if the disks are badly worn or if disks that are designed to operate dry become covered with oil or grease.

If the plates of a dry disk clutch are found to be

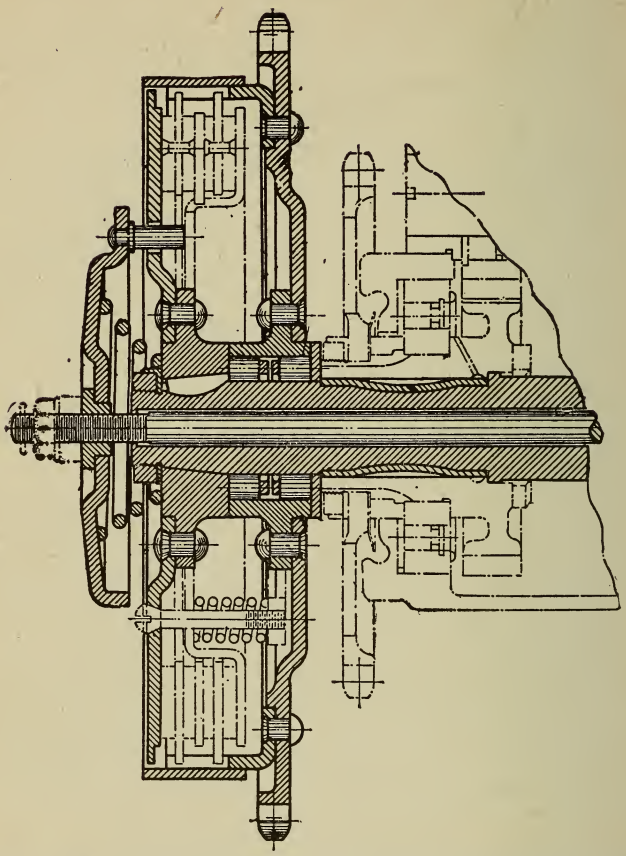

Figure 106.—Clutch Actuated by Single Coiled Spring (Harley-Davidson).

greasy or glazed, it will be necessary to remove them and to clean the surfaces with gasoline. The surface of the disks can be slightly roughened with a wire brush. It is a somewhat common practice to burn the oil out of clutch facings with a blow torch. While

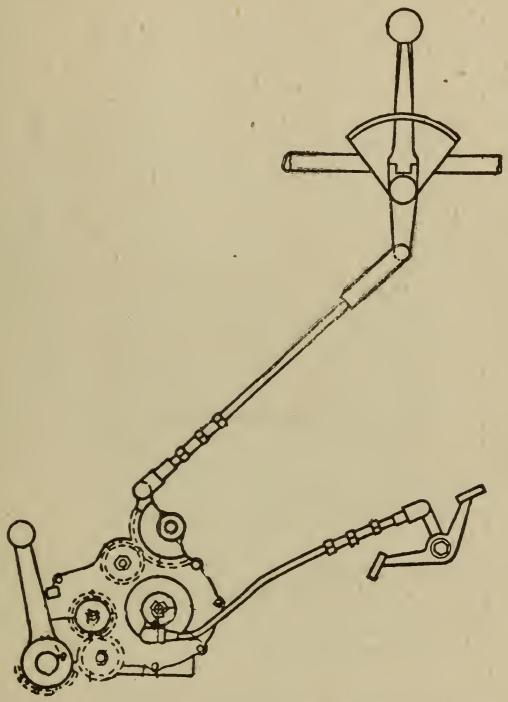

Figure 107.—Lever and Pedal Controls for Clutch and Gear Set (B. S. A.).

this method is effective in removing oil there is some danger of warping the metal plates on which the friction surfaces are mounted.

When adjusting the tension of a clutch having

several springs, care should be used to turn each adjusting bolt or nut exactly the same number of turns or parts of a turn regardless of how hard some of them may turn and how easy it may be to move the others. After a clutch is adjusted it may be tested by placing the machine on the stand, and with the clutch engaged, attempting to turn the rear wheel. Should it be found that the clutch tends to grab in spite of careful adjustment it may be necessary to place a few drops of oil on the friction surfaces.

If new disks are fitted in a clutch it is important that their slots or openings fit the clutch keys properly. A proper fitting means that there is practically no side play, while the disk is still free to move endwise along the key, especially along that portion of the key which carries the disk while in working position. If the disks are loose on the keys the clutch will be noisy. In taking a clutch apart it is a good plan to mark each of the plates, both as to their position with reference to each other and for their position on the keys.

THE GEAR-SET

A majority of motor cycles are fitted with a series of gears which allow three different ratios of speed between the engine and drive wheel. A few machines provide only two forward speeds while still others have three forward speeds and also a reverse gear. Because of the general use of the three speed gear it will be described in detail.

A typical three speed gear box is shown in Figure 108. Within the housing are carried two shafts, the upper one being called the main shaft and the lower one *C* being called the counter-shaft. The main shaft

has its right hand end carried by a ball bearing in the housing, while its left hand end passes through the center of a gear and a sprocket and extends out to the taper shown at the extreme left. On the main shaft is mounted a sliding member consisting of the gears *2* and *4* together with the jaws *B*, these three

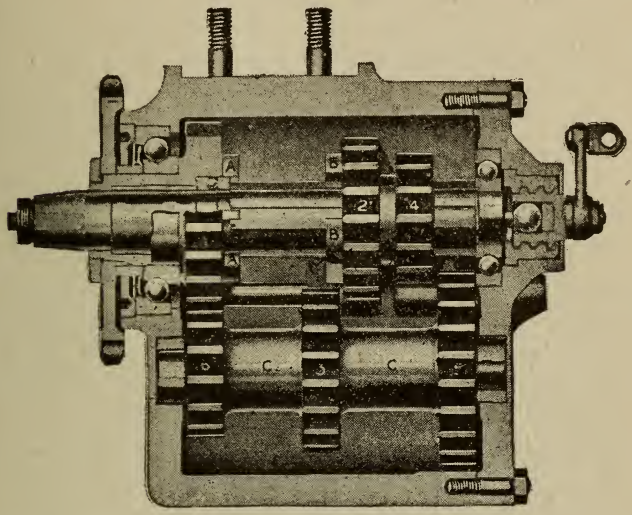

Figure 108.—Parts of Three Speed Gear-Set. A, B: High Speed Jaws. 1: Constant Mesh Sprocket Gear. 2: Intermediate Speed Main Shaft Gear. 3: Intermediate Speed Countershaft Gear. 4: Low Speed Main Shaft Gear. 5: Low Speed Countershaft Gear. 6: Constant Mesh Countershaft Gear (Indian).

parts being made in one piece and adapted to slide along splines formed on the outside of the main shaft. The counter-shaft carries three gears, *3*, *5* and *6*, formed in one piece with the shaft. Power from the engine comes to the gear-set through the clutch to the tapered end of the main shaft. With the engine

running and the clutch engaged, the main shafts together with gears *2* and *4* are put in motion but as neither *2* nor *4* are in mesh with the counter-shaft gears, no power is transmitted through the gear-set.

When it is desired to engage low speed in which the engine runs fast compared to the road wheel, the sliding member on the main shaft is moved to the right until gear *4* engages gear *5*. Power now passes through the main shaft and gears *4* and *5* to the counter-shaft. As gear *4* is smaller than gear *5* the counter-shaft runs at less speed than the main shaft. Gear *6* on the counter-shaft is always in mesh with gear *1* and gear *1* is attached to the spocket which is shown in section at the left hand side of the illustration. Over this spocket passes the drive chain which carries power to the rear wheel. Inasmuch as gear *6* is smaller than gear *1*, gear *1* and the drive sprocket run at a lower speed than that of the counter-shaft so that the total reduction of speed between the main shaft and the drive sprocket is considerable.

When the intermediate gear ratio is to be used the sliding member of the main shaft is moved to the left until gear *4* leaves its engagement with gear *5* and until gear *2* meshes with gear *3* on the counter-shaft. As the gears *2* and *3* are of the same size, the counter-shaft now runs at the same speed as the main shaft and the only reduction remaining is due to the difference in size between gears *6* and *1*.

When high speed or direct drive is to be used the sliding member on the main shaft is moved still farther to the left until gear *2* passes out of engagement with gear *3* and until jaws *A* and *B* lock together. The drive sprocket and the main shaft now run at the same speed.

A construction in which the sliding member consists of one gear and two sets of jaws is shown in Figure 109. With this design there are two sets of constant mesh gears, these being shown at the extreme ends of the two shafts. With the sliding member moved to the right the low speed jaws are engaged and the

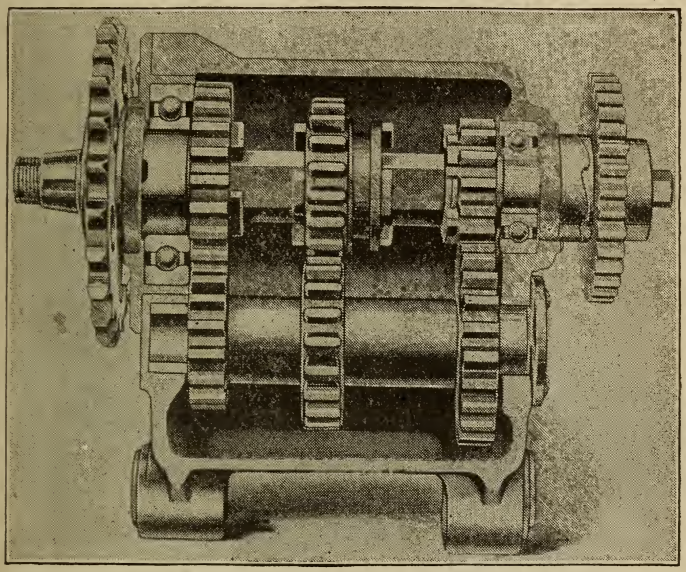

Figure 109.—Gear Set Having Two Pairs of Constant Mesh Gears and Two Pairs of Jaw Clutches (Reading Standard).

sliding member locks the adjacent small gear to the main shaft through the jaws. Otherwise the action is similar to the gear-set already described. In Figure 108 the connection for the kick starter is shown at the right hand end of the main shaft. Another transmission using jaw clutches is shown in Figure 110.

Various gear ratios are used, the reduction depending upon the weight of the motor cycle and the power of its engine. The average in direct drive is four and a half to one, but the range is from three and three-quarters to one up to six to one. The average reduction in intermediate is a little greater than seven to one, while the average reduction in low speed is about ten and one-half to one. When the reverse is used

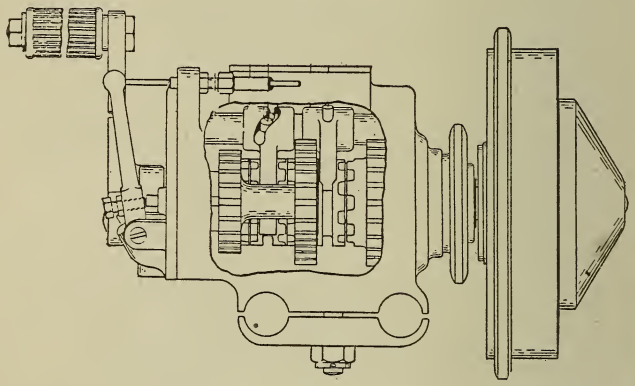

Figure 110.—Gear Set With Two Pairs of Jaw Clutches (B. S. A.).

its reduction is usually somewhat greater than low speed, often being about twelve to one.

It will be noticed that in the gear-sets so far described, it is necessary to pass through intermediate speed when going from low to high. This type of construction is known as a progressive sliding gear transmission. Another type is generally used when a reverse gear is supplied. In this other type, called a selective sliding gear, the sliding member on the main shaft is made in two separate parts, one part

being moved to engage low speed and reverse while the other part is moved to engage intermediate and high. With such a construction either of the sliding members may be moved independently of the other so that it is possible to pass from any one ratio

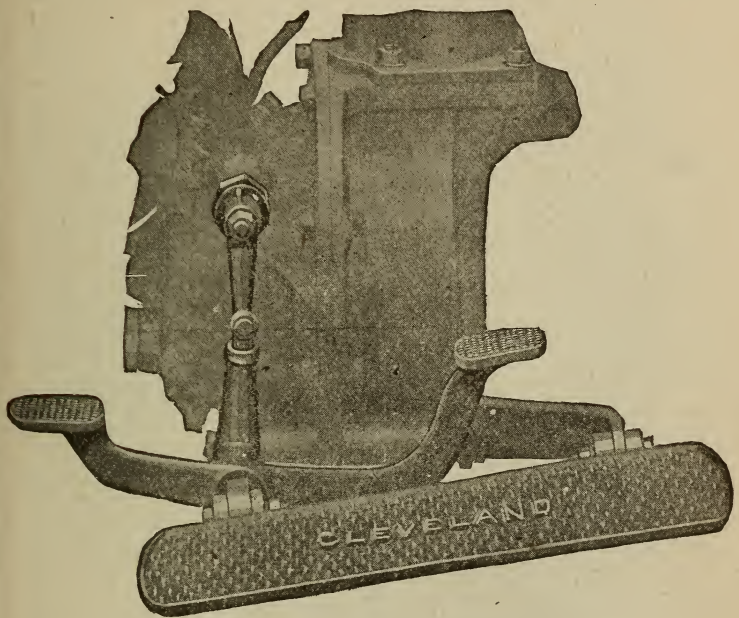

Figure 111.—Heel and Toe Pedal for Operating Two Speed Transmission.

directly to any other ratio without going through any of the speeds that are not to be used.

As a general rule, the transmission and clutch form a unit separate from the engine and mounted on the frame just back of the engine. In other designs the transmission may be built in a unit with the engine, this often being the case with four-cylinder machines.

With some machines, especially with those providing only two speeds, the transmission gears are controlled by a double foot pedal as shown in Figure 111. Pres-

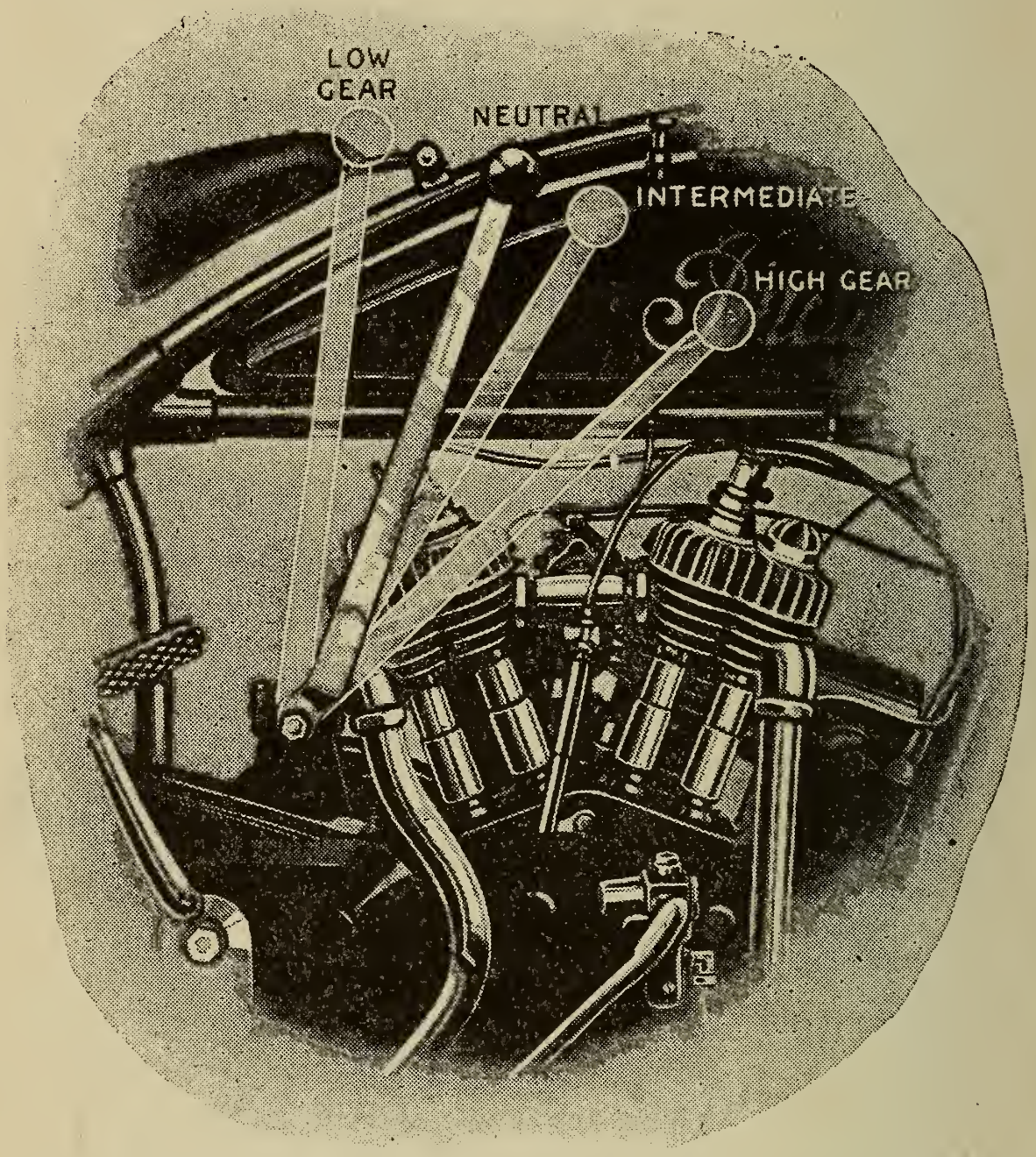

Figure 112.—Positions of Gear Shift Lever for Three Speed Transmission (Indian).

sure on the forward pedal engages one of the ratios while pressure on the rear pedal moves the lever in the opposite direction and engages the other ratio.

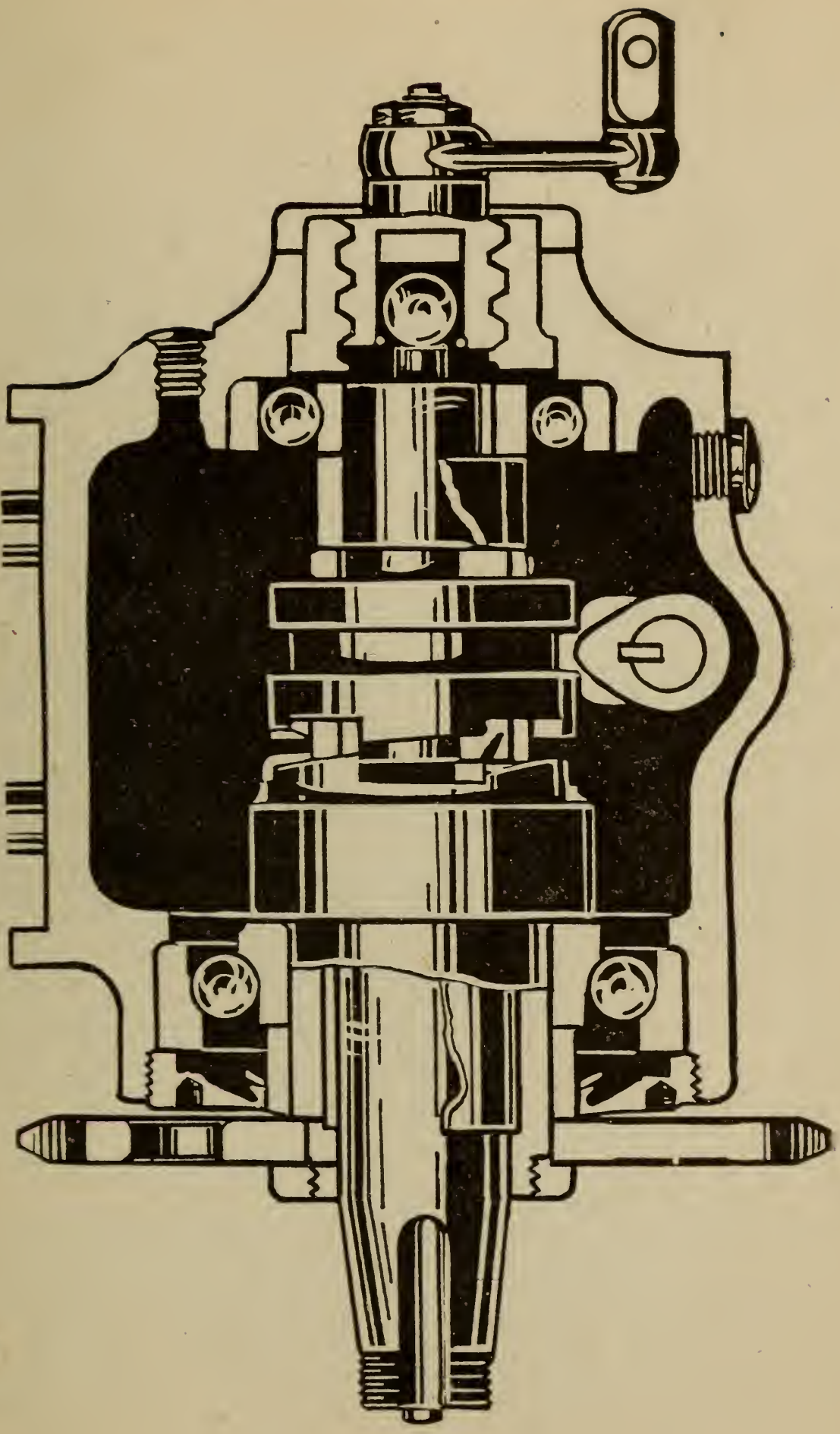

Figure 113.—Free Engine Clutch (Indian).

The several positions for the control lever of a three speed progressive transmission are shown in Figure 112.

Some machines are provided with a device called a free engine clutch shown in Figure 113. This simply consists of a jaw clutch which may be moved into or out of engagement. When it is engaged, the engine drive is carried through the tapered shaft to one clutch member and through the clutch to the driving sprocket. Such a device provides a suitable location for the kick starter.

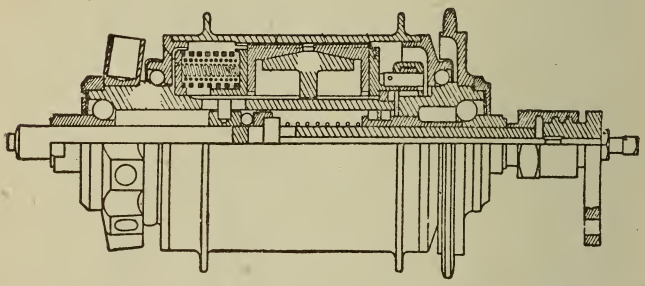

Figure 114.—Free Engine Clutch Mounted in Wheel Hub (B. S. A.).

A type of free engine device mounted in the wheel hub is shown by Figure 114. The clutch proper consists of three members, a steel central clutch piece having conical faces, and two phosphor bronze end clutch pieces which are tapered internally and adapted to engage with the steel central clutch piece

The central clutch piece is engaged with the driving center to which is attached the belt pulley and the two phosphor bronze end clutch pieces are fixed in the hub shell. On the end of the driving center opposite the belt pulley is attached the free wheel mech-

anism, and the pawl carrier also forms an abutment plate for the clutch pieces.

On the belt pulley end of the driving center, there is a fixed spring plate which takes the pressure of the springs, and in between the springs and the phos-

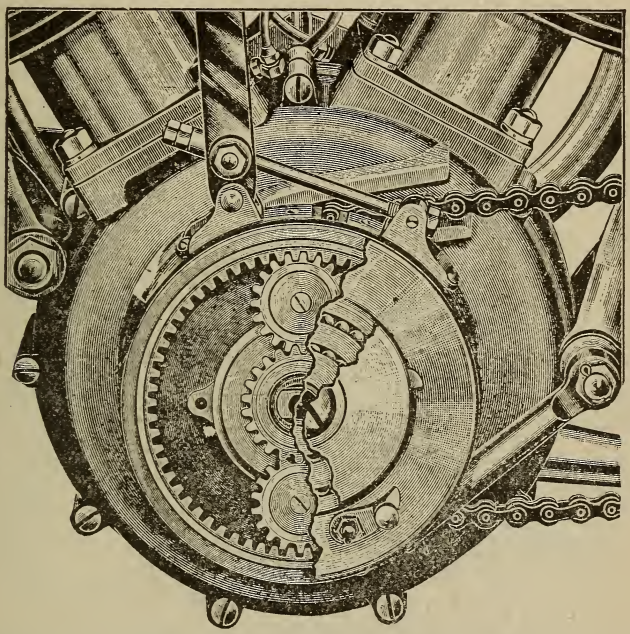

Figure 115.—Two Speed Planetary Transmission (Iver-Johnson).

phor bronze end clutch piece is another plate which is actuated by means of the rod in the center of the spindle either to free the clutch, or to allow the springs to exert their pressure on the clutch pieces. By reason of the wedging action of the phosphor bronze pieces being forced onto the steel central clutch

piece, the driving center is enabled to drive the hub shell. It will be seen that when the clutch is in action the spring thrust is self-contained and exerts no pressure on the ball races.

In Figure 115 is shown a planetary type of two speed transmission. This arrangement consists of a

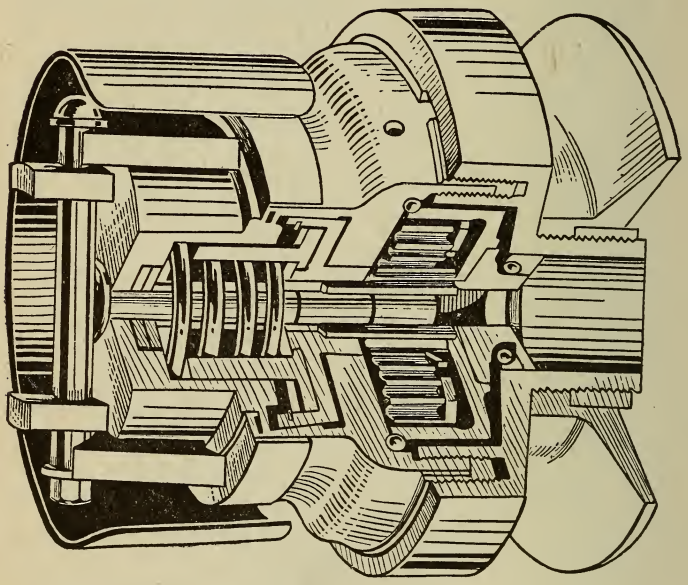

Figure 116.—Planetary Transmission Showing High Speed Clutch and Belt Pulley (Bradbury).

central gear driven from the engine crankshaft. In mesh with this central gear are two or more small planetary pinions and these pinions are arranged to travel inside of a large internally toothed gear. The pinions are mounted on a plate which is in turn attached to the drive sprocket. When it is desired to

obtain a reduction of speed the internally toothed gear is held stationary by means of the band which is shown. With the central gear being driven by the engine, it causes the planetary pinions to travel around the inside of the internal gear but they travel at a rate of speed that is much less than the engine speed. High gear is secured by locking all of the gears together through a clutch so that they revolve as a unit and at the same speed as the engine. Another planetary gear operating upon the same principle but showing some difference in construction, is shown in Figure 116.

Transmission Operation and Care.—With the sliding gear type of transmission, the shift from one ratio to another should only be made while the clutch is held released. When attempting to engage low gear, if it is found that the control level does not easily move into position it is due to the fact that the gear teeth or the jaws are meeting end-on. The trouble may be overcome by moving the motor cycle backward or forward.

After low gear is engaged and the machine has been started in motion, the change to intermediate speed should be made without delay. The control lever should be moved quickly but should not be moved with a jerk. It is not safe to attempt to shift gears while running at speeds in excess of fifteen miles an hour because such practice will probably result in mechanical damage.

If the engine has been stopped with the gears in the high speed or intermediate speed position, it will be found difficult if not impossible to move the control into the low speed position. The shift may be made under these conditions if the lever is pulled

while the engine is cranked by means of the starter.

In shifting downward from high speed to intermediate or from intermediate to low, it will be found to facilitate matters if the engine is slightly speeded up while making the change, this being just the reverse of the shift to higher gears in which the engine speed

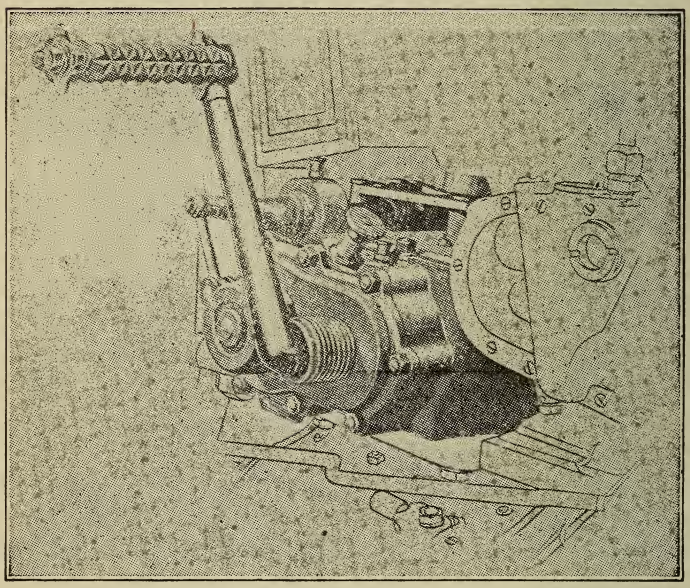

Figure 117.—Mounting of Kick Starter Pedal (Harley-Davidson).

should be reduced. When shifting down it will be found best to release the clutch but slightly while making the change.

The gear-set does a great deal of work and requires proper and ample lubrication. The gear box should have a supply of heavy oil such as steam engine cyl-

inder oil or extra heavy gasoline engine oil. No kind of grease should be used in a transmission having ball or roller bearings. Gear boxes are designed to be filled from one-third to two-thirds full of lubricant but they should never be completely filled.

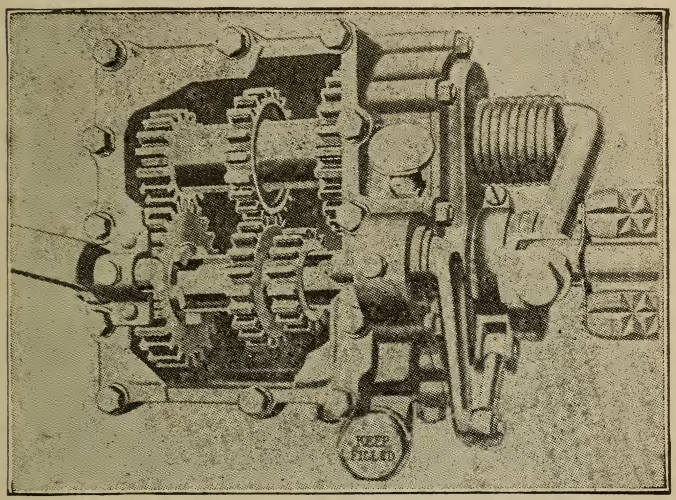

Figure 118.—Kick Starter Connection with Gear-Set (Harley-Davidson).

KICK STARTERS

Motor cycle engines are generally cranked by means of a foot operated device attached to the gear-set and known as the kick starter. In a majority of cases the starter acts on the counter-shaft through a ratchet or an auxiliary sliding gear or some other means of engagement. The external appearance of one such starter is shown in Figure 117. By pushing down on the foot pedal the transmission shafts are rotated

and through the driving connection the engine crankshaft is revolved. The relation of the starter to the gear-set is shown in Figure 118. In the particular installation just mentioned, connection between the pedal and the transmission shaft is secured through a gear on the shaft and a segment of a gear attached to the pedal as shown in Figure 119. This device is fitted with an adjusting plunger *3*. If the teeth of

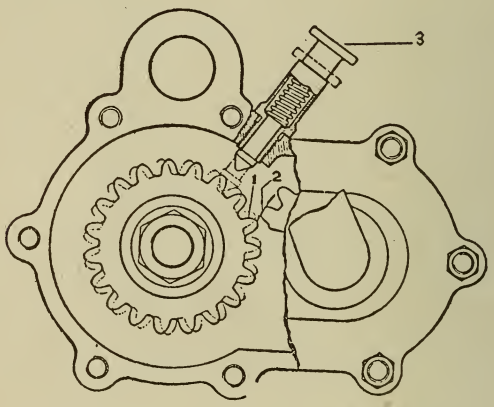

Figure 119.—Kick Starter Gear Meshing Device (Harley-Davidson).

the segment fail to engage with the teeth of the gear because teeth *1* and teeth *2* do not align, stepping on the plunger will bring the gears into mesh.

The arrangement of parts in another form of kick starter is shown in Figure 120. In this case the segment engages with a gear carried outside of the ratchet and connecting with one of the transmission shafts. An arrangement by means of which the starter operates through an auxiliary shaft and gear extending into the transmission is shown in Figure 121. The

connection of the starter pedal on the unit power plant with a four-cylinder engine is shown in Figure 122.

Using the Starter.—When the engine is to be cranked by means of the kick starter, the spark and

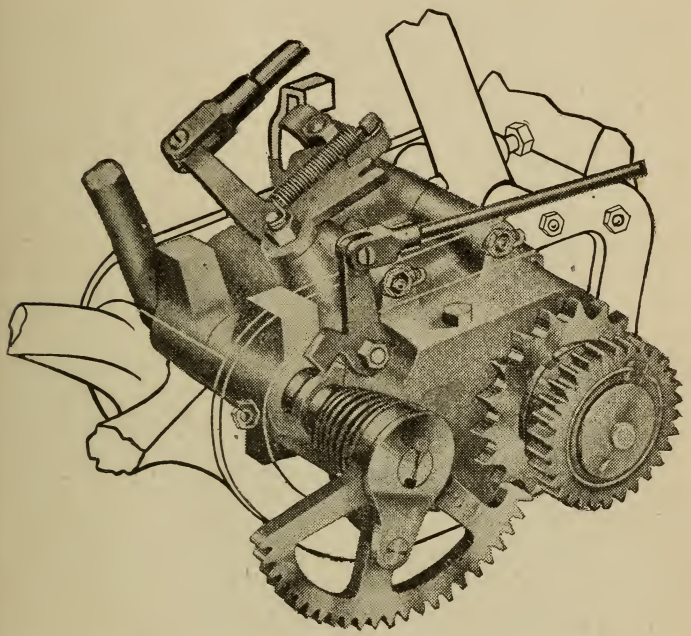

Figure 120.—Kick Starter Segment and Gear (Excelsior).

throttle controls are set in their correct position for this purpose, the compression release is raised and the clutch allowed to remain engaged. Depending on the construction of the starter, the transmission gears are placed either in the neutral, the low speed or the high speed position.

The starter pedal is brought into its operating position and pushed downward until the engine compression is felt. The starter pedal should then be allowed to return to the beginning of its stroke. The pedal is then pushed down quickly and when it is about half way through the stroke, the compression release is dropped. The engine should then start to fire but if it does not do so the starter is again used in the same manner. After the pedal has been pushed all the way down it should not be allowed to fly back under the action of its return spring because this will quite likely result in breakage. The operator's foot should be kept on the pedal until the parts have returned to their inoperative position.

CHAIN DRIVE

Cleaning and Lubrication.—The drive chains should be cleaned and lubricated at least once in each one thousand miles running because a dirty or poorly lubricated chain will give a jerky drive, will break easily and will tend to ride the sprockets. In many cases the short front driving chain is lubricated by oil vapor coming from the engine but this lubrication alone is not sufficient and both front and rear chains should be treated alike. The application of lubrication only to the outside links which are exposed is not the proper way to do this work.

The chains should be removed and placed in a bath of kerosene or gasoline. In this bath the chain can be washed about until all grit and dirt is carried away. The chain should then be allowed to dry. Lubrication is applied by melting a specially prepared compound or else by making a mixture of tallow and graphite

which is also used while melted. The chain should be placed in this lubricant and allowed to remain while heat is applied for ten or fifteen minutes so that the grease is able to reach underneath the rollers. The chain should be moved about while in the lubricating

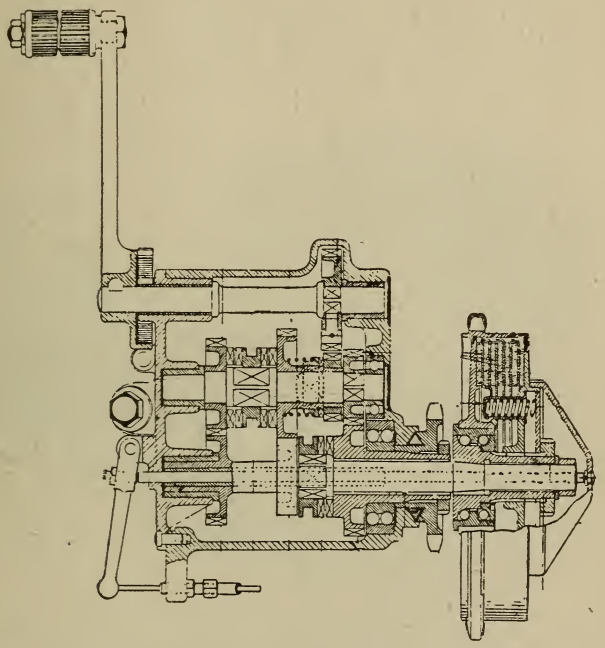

Figure 121.—Kick Starter Carried Into Gear-Set Housing (B. S. A.).

bath. After the chain is removed and allowed to cool, the excess grease is wiped away with a clean cloth after which the chain is ready for use. Chains that run enclosed do not require attention as often as those which are exposed. The enclosed chains are

generally run with a quantity of thick oil in the bottom of the case.

Chain Adjustment.—If a drive chain is run too tight it will break, while if it is run too loose it will jump the sprockets. Motor cycle chains are adjusted somewhat tighter than are those on bicycles because of the steadier drive with the motor cycle. Both the long and the short chains should be adjusted so that they have a sag of about one-half inch on the lower

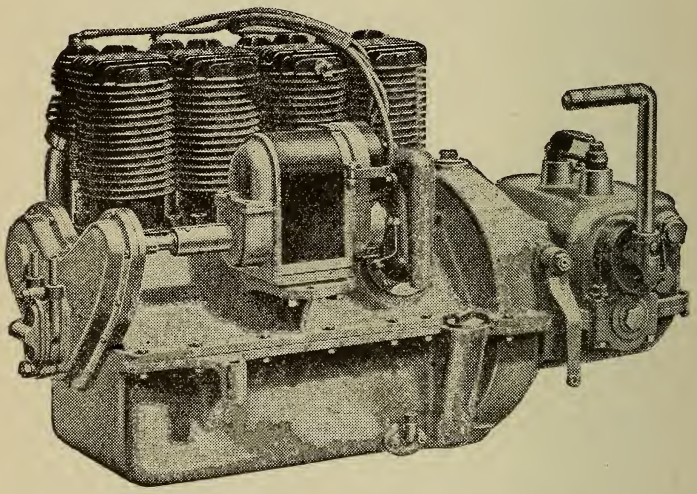

Figure 122.—Kick Starter Mounted on Unit Power Plant (Henderson).

side. This sag should be tested at various points while turning the rear wheel until a full revolution has been made. The adjustment should be made while at the tightest point. In most designs the tension of both front and rear chains is dependent on the position of the gear-set. Therefore, if the front chain is adjusted

it will usually mean that the rear one also must be cared for. When both chains are to be attended to, the front one should be adjusted first.

The driving chain between the engine and transmission is usually adjusted by loosening the fastening of the gear-set and moving the box into the correct position where it is firmly locked. After a front chain adjustment it will often be found necessary to change the length of the clutch and gear-shift controls. The rear drive chain is adjusted by loosening the fastenings of the wheel hub and moving the hub backward until the desired tension is secured. This movement may often be made with adjusting screws, one on each end of the hub. Care should be used to turn each screw exactly the same amount. After the chains have been adjusted the motor cycle should be placed on its stand and the rear wheel turned slowly while checking the tension in several positions. If the tension is found correct the engine should be started and the various controls should be operated to see that they are correctly set.

Chain Alignment.—Two sprockets over which a drive chain is running must be exactly in line with each other. If the sockets are in line the chain will not touch the sides of the teeth, while if they are out of line there will be interference and damage due to the wear on both chain and sprocket. If an examination of a chain shows signs of wear on the inside of the side plates of the links it indicates a misalignment.

The sprocket position cannot be correctly determined by sighting. The correct method is to hold a straight-edge solidly across the face of one sprocket, preferably the larger one, and to allow the other end of the straight-edge to rest in the space between two

teeth of the other sprocket. If the sprockets are in line the end of the straight-edge will come flush with the bottom face of the teeth (not at the top of the teeth).

Chain Renewal.—While a chain is removed for cleaning and lubricating, each link should be inspected. If any of them show a great amount of play between the pins and rollers, if they show broken rollers or if they contain loose pins, the defective links should be removed and replaced with new ones. The sprockets should also be examined for excessive wear on the driv-

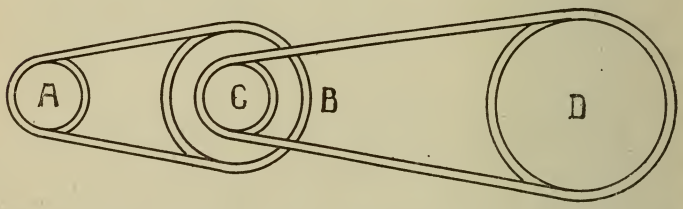

Figure 123.—Layout of Double Chain Drive. A: Engine Driving Sprocket. B: Front Driven Sprocket. C: Front Driving Sprocket. D: Rear Driven Sprocket.

ing or front side of the teeth. The teeth will wear hook-shaped in time and this will prevent proper meshing of the chain. The small sprockets will show more wear than the large ones. If a new chain is put on badly worn sprockets, it will make an unsatisfactory drive and the new chain will soon be ruined.

Gear Ratios.—Chain drives are usually laid out somewhat as shown in Figure 123. Sprocket *A* is the engine sprocket; *B* is the front driven sprocket; *C* is the front driving sprocket; while *D* is the rear wheel sprocket. To find the gear ratio, the number of teeth on the rear wheel spocket *D* is multiplied by the num-

ber of teeth on the front driven sprocket *B*. This product is divided by a number found by multiplying the number of teeth on the engine sprocket *A* by the number of teeth on the front driving sprocket *C*, the quotient being the total gear ratio. Using the letters shown in the diagram, this method may be explained by the following formula:

$$D \times B \div A \times C$$

BELT DRIVE

Driving belts should be kept clean and free from collections of grease, dirt and engine oil. They should occasionally be wiped with a moist cloth. No mineral lubricating oil such as engine oil should ever be applied to a belt and neither should any vegetable oil such as castor oil be used. In order to keep the belt soft and pliable it may be given a light application of neatsfoot oil once during each two or three weeks' driving. It may occasionally be necessary to clean the sides of a V belt with a file in order to remove dirt and roughness. Belt fastenings should be oiled and kept free from rust.

Belt Adjustment.—Belt tension should be such that there is little or no slipping under any conditions of driving but it should not be so tight as to strain the bearings of the pulleys at either end. With a correct tension the belt will not slip when the motor cycle is pushed forward against the compression of the engine. The lower the gear ratio, that is, the faster the engine runs for a given road speed, the tighter the belt must be. A tight belt will wear faster than a loose one, although excessive looseness will cause wear because

of the slipping that takes place. A belt may be made tighter by cutting off a short piece from one end and then replacing the fastener, or else by the use of an adjustable pulley.

Should it be necessary to remove the belt it will be best handled by removing it from the large pulley first and by replacing it over the small pulley first. When the belt is to be removed start it over the rim of the large pulley. When it is to be replaced put the belt over the engine pulley, then over the top of

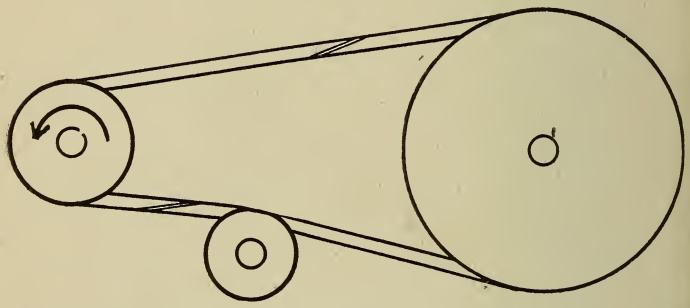

Figure 124.—Lapping the Splices in a V or Flat Belt Drive.

the large pulley, and turn the road wheel backward to finish the replacement.

A spliced belt should be put over the pulleys in such a direction that the splice will be rolled down as it runs over the idler pulley if one is used. Should the splice start to curl up, the loose ends should be trimmed off and the direction of the belt's running should be looked after. The proper position for the splice is shown in Figure 124.

Belt Pulleys.—Some machines having a belt drive are equipped with an adjustable pulley which allows of belt tightening or of a ready change of gear ratio.

Such pulleys are made for use with V belts and the outer flange of the pulley is made so that by turning it one way or the other the distance between the flanges will be increased or decreased. With the distance increased, the belt will lie lower in the pulley and the gear ratio will be lower. With the distance decreased the belt will ride higher and the gear ratio will be

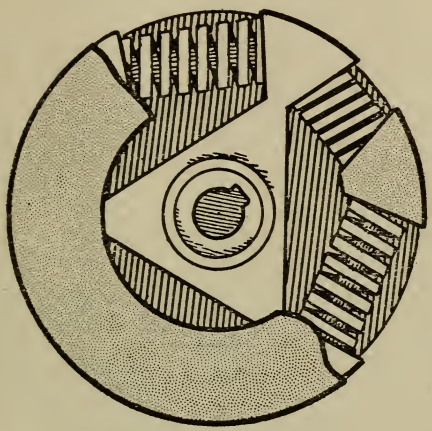

Figure 125.—Cushion Drive (B. S. A.).

higher. Such adjustment will call for change in the length of the belt. This is sometimes cared for by having a comparatively short length at some one point in the belt and then carrying other lengths already fitted with the necessary parts of belt fastenings.

OTHER DRIVES

Many chain drives are fitted with cushion sprockets similar to the one shown in Figure 125. In this case the engine drives the central member which is shown

in white. The sprocket teeth or the pulley flanges are attached to the part shown shaded. Between the driving and driven members is a series of coiled springs, which by their compression and expansion

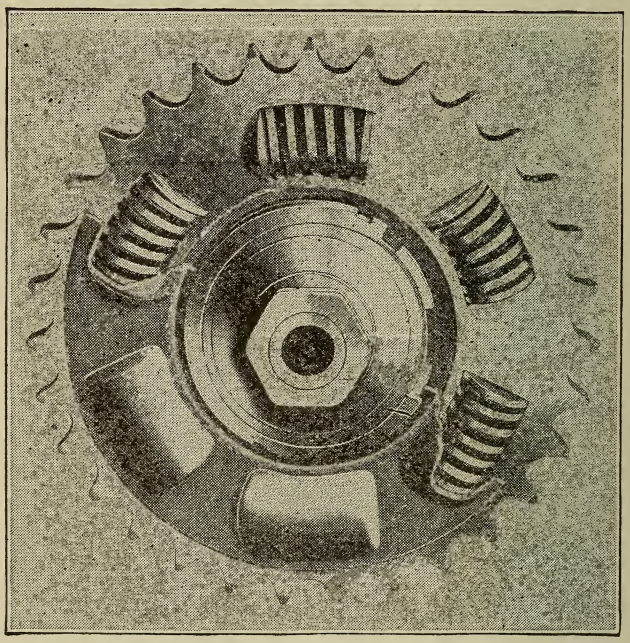

Figure 126.—Cushion Drive Sprocket (Excelsior).

absorb any small shocks due to the power impulses of the engine. Another cushion drive sprocket is shown in Figure 126.

A worm gear drive for motor cycles is shown in Figure 127. This consists of a steel worm attached to and driven from the transmission shaft. This worm drives a worm gear which is made of bronze and this

worm gear in turn drives through the clutch and chain to the rear wheel.

BRAKES

Motor cycle brakes were originally the same as, or very similar to, the coaster brake used with bicycles.

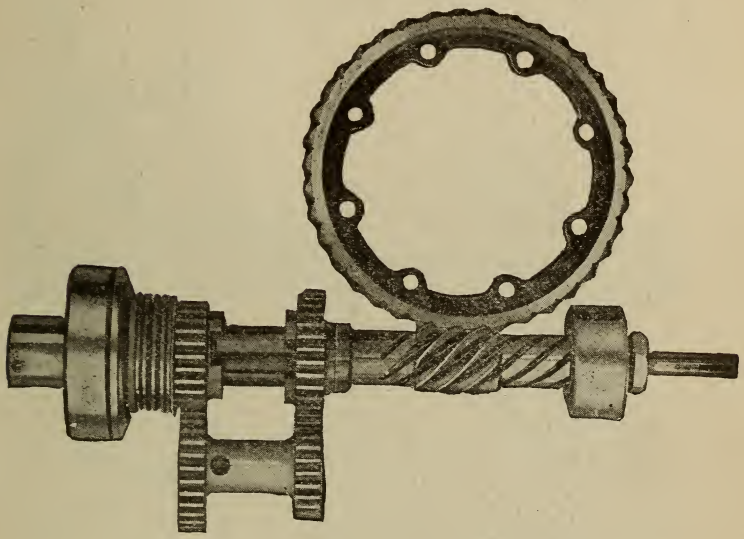

Figure 127.—Worm Gear Drive (Cleveland).

A motor cycle type is shown in Figure 128. In the larger and more powerful machine these coaster brakes have given way to brakes designed very much along the lines of those used with automobiles, that is, brakes of the drum type with an expanding shoe inside the drum or with a contracting band outside the drum. In many cases the brake is made with both an internal shoe and an external band. Brakes are usually con-

trolled from a foot pedal although in a few cases a hand grip is used. In American practice the brake is located on the hub of the rear wheel. In foreign machines brakes are also found applied to the belt pulley on the rear wheel as shown in Figures 129 and 130, and to a special brake pulley fastened to the front wheel as shown in Figure 121.

The parts of a drum brake having internal expand-

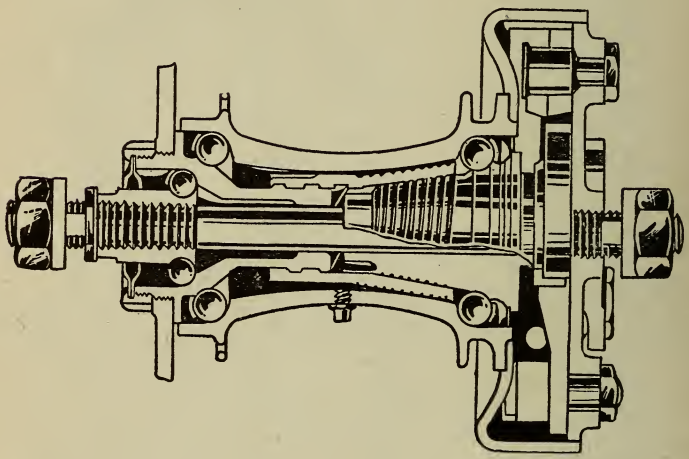

Figure 128.—Motor Cycle Type of Coaster Brake (New Departure).

ing shoes are shown in Figure 132. The shoes are expanded by movement of the cam at the upper end of the operating lever and they are returned to a released position by the upper coiled spring. The operating lever is returned to its released position by the lower coiled spring.

Another internal expanding brake is shown in Figure 133. This brake is adjusted by removing the

cotter pin *1*, loosening the nut *2*, then loosening the lock nut *3*, and turning the screw *4* to the right. At *5* is shown the adjustment for length of the pull rod.

Figure 134 shows a brake that includes both an internal shoe and an external band. This brake is

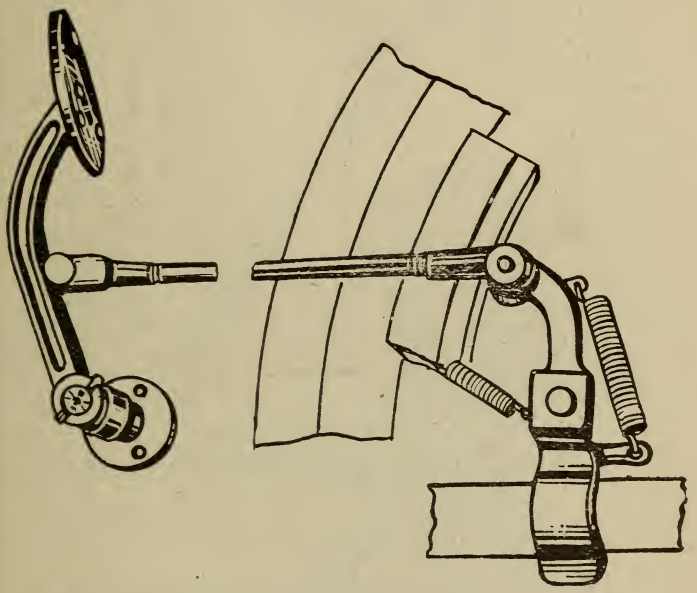

Figure 129.—Brake Applied to Rear Wheel Belt Pulley (Bowden).

adjusted by removing cotter pin *1*, loosening nut *2*, and lock nut *3*, and turning the screw *4* to the right in the manner similar to that used with the brake just described. Both adjustments for the pull rod *7*

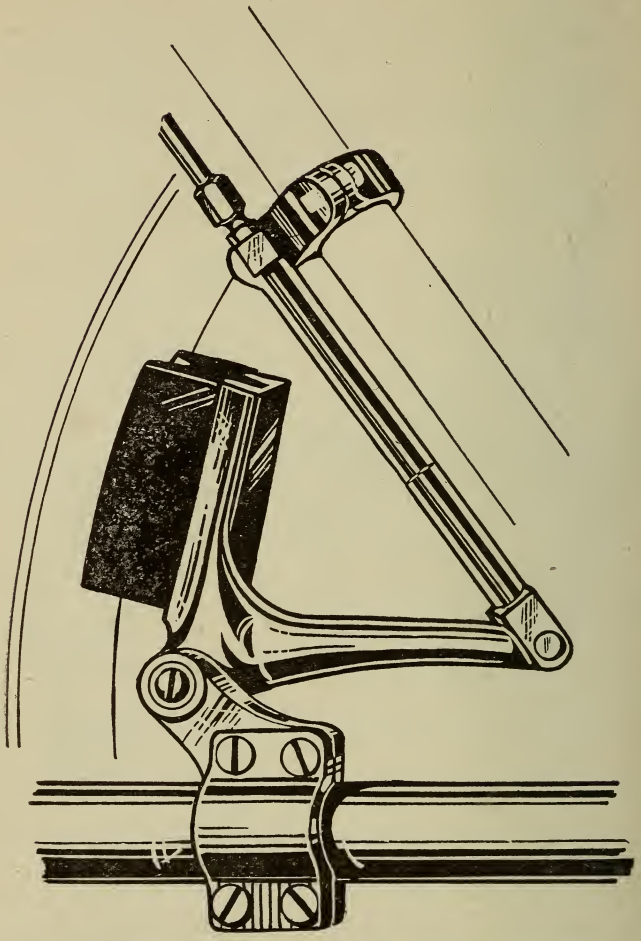

Figure 130.—Brake Applied to Rear Wheel Belt Pulley (Bowden).

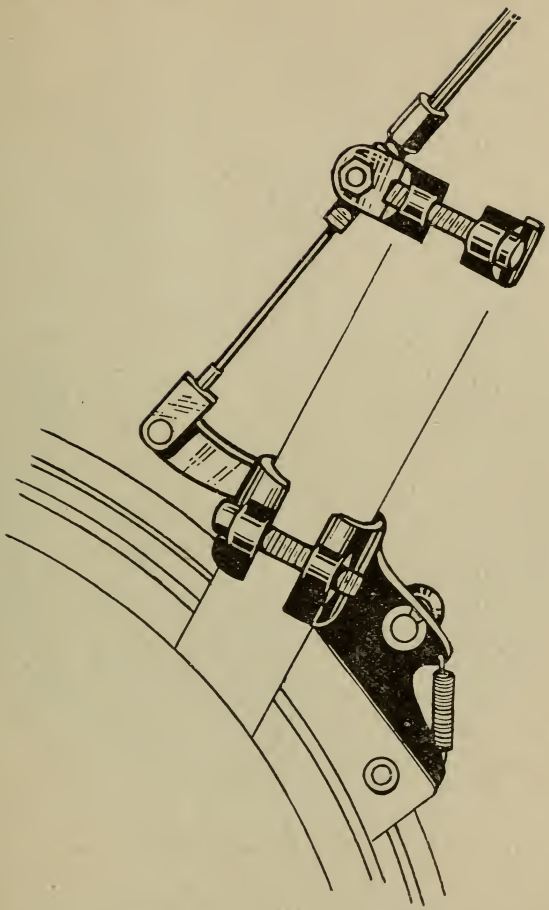

Figure 131.—Brake Applied to Front Wheel (Bowden).

are shown at the points *5* and *6*. The external brake is adjusted by removing pin *A*, lifting screw *B* from the clevis where connected to *A* and turning *B* into *C* by screwing it to the right. The drum is shown at *D*. This brake is operated by a flexible wire held on the frame by the clamp *E*. Another construction of

Figure 132.—Internal Expanding Brake (New Departure).

internal and external brakes is shown in Figure 135.

Brake Adjustment.—If the motor cycle is driven carelessly and run close to the stopping point before shutting off the power, excessive use of the brakes will be made necessary and they may require adjust-

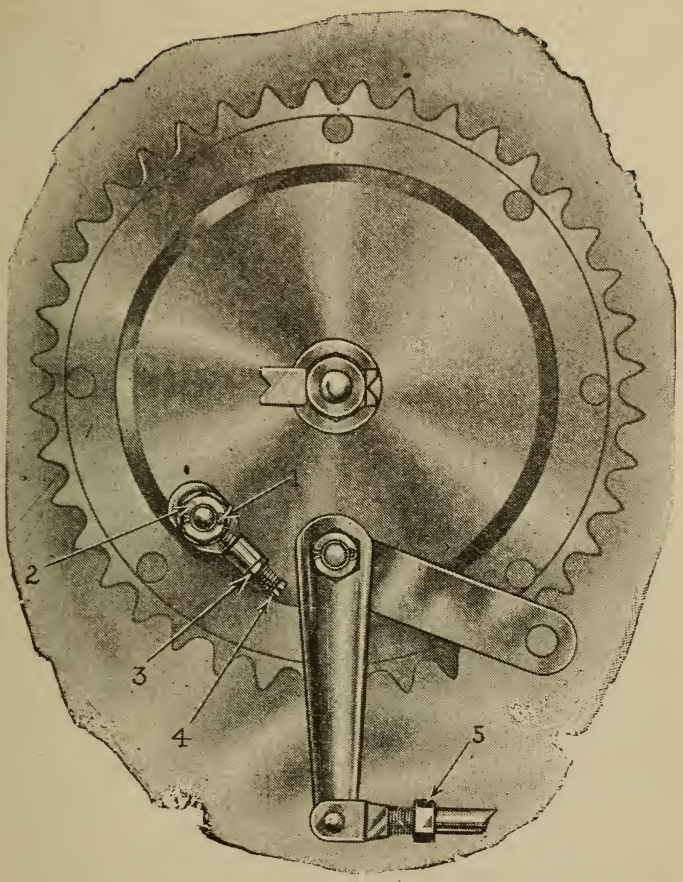

Figure 133.—Adjustments for Internal Brake on Indian Scout.

ment as often as once in every five hundred miles. If the rider is more careful and allows the machine to slow up through inertia the brakes may operate for four or five thousand miles between adjustments. Adjustment will often be found unnecessary if the operating parts, the pull rod ends and levers, are

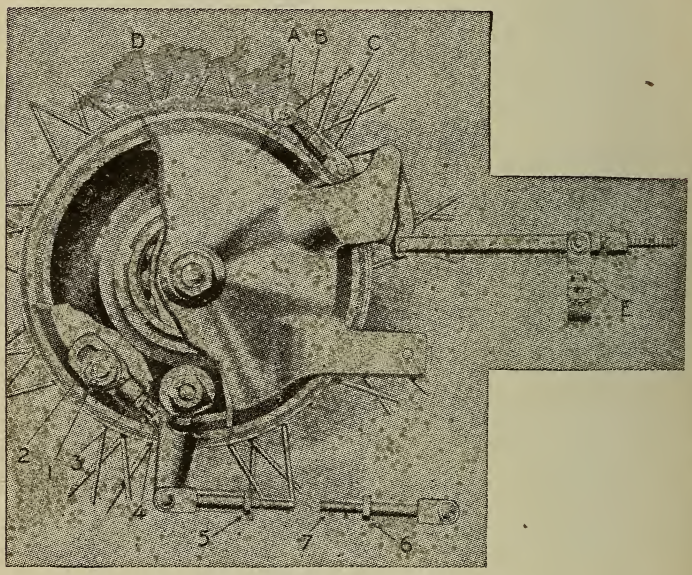

Figure 134.—Adjustments for Internal and External Brakes (Indian).

cleaned and oiled so that the brakes will release fully and so that they may be easily applied. If the brakes squeak or grip the fault may often be overcome by applying a small amount of powdered chalk or talcum powder to the brake lining. The brake adjustment

should always be tested after the chains or the driving belt have been tightened.

With the machine fitted with both external and internal brakes, the external band should be used under all ordinary conditions because it is easier to keep the external brake in adjustment and when worn

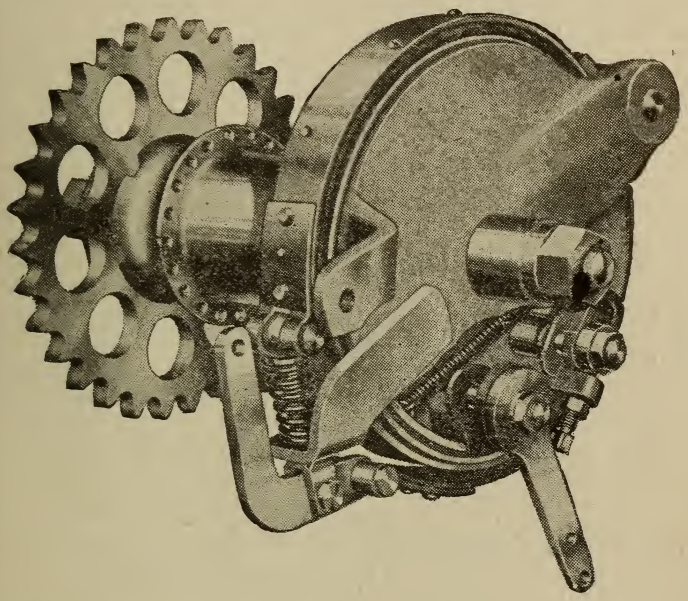

Figure 135.—Internal and External Brakes (Excelsior).

out it is easier to replace the lining of this band than it is to perform similar operations on the internal brake. If the machine is fitted with a front wheel brake that member should be used only in an emergency and it should never be used on slippery roads.

Engine as a Brake.—The brakes may be relieved of

a great deal of work by using the compression of the engine to retard the motion of the machine. With the ignition turned off, the clutch engaged, and the high speed ratio in use, the engine will exert a very considerable braking effect and will bring the motor cycle to a stop within a fairly short distance. If this same procedure is followed except for the use of intermediate or low gear in place of high, the retarding effect will be increased greatly. In using the engine as a brake, a certain amount of flexibility may be secured by slipping the clutch which is then in effect, the brake.

Before descending a steep hill it is advisable to engage high or intermediate gear so to be ready to use the engine to hold the machine in check. If the engine stops, do not attempt to start it while coasting by engaging the clutch with low or intermediate gear in use for the drive will be seriously strained or broken.

CHAPTER VIII

RUNNING GEAR

The parts of a motor cycle which comprise the running gear include the frame for supporting the power plant, the front forks, the rear suspension, the wheels with their hubs, and the tires. All of the parts of such a running gear with the exception of the wheels, spokes, and rims, are shown in Figure 137.

General Lubrication.—The points at which lubrication is required on a typical motor cycle are shown in Figure 136. The numbers indicate the following items and after each item is mentioned the kind of lubrication that is used.

1. Rocker arms, grease or oil.
2. Front hub, cup grease.
3. Rocker arm pivot, oil.
4. Head bearing, cup grease.
5. Control joints. Follow these throughout machine. Machine oil.
6. Spring pivots, oil.
7. Springs. Spread leaves with screw driver and insert graphite grease.
8. Brake lever pivots and clutch, oil.
9. Seat post pivots, oil.
10. Seat post, oil. Remove and grease occasionally.
11. Saddle springs, oil.
12. Rear hub, cup grease.

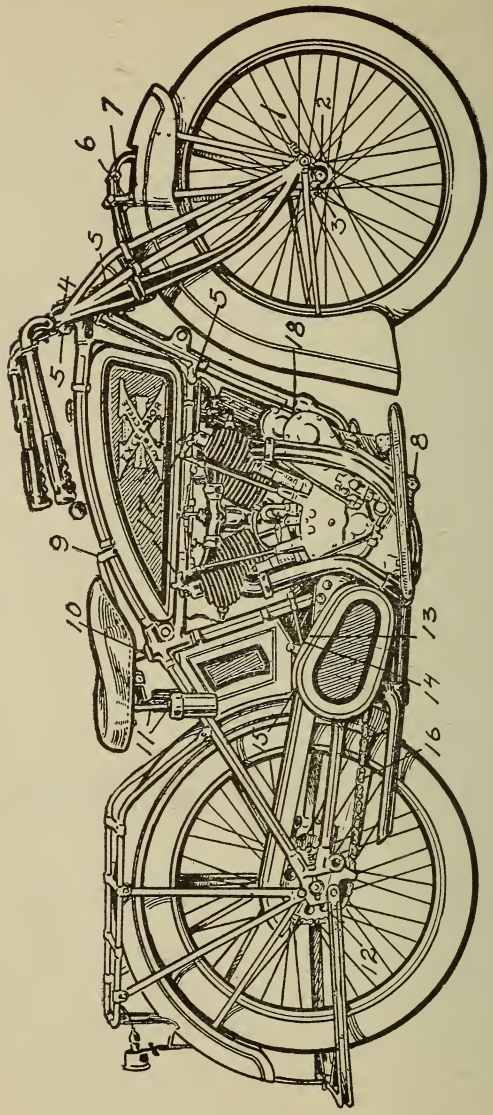

Figure 136.—Lubrication Chart (Excelsior).

13. Transmission, heavy oil.
14. Compression release, oil.
15. Starter pedal shaft, oil.
16. Chain, graphite and tallow.
17. Intake valve rocker arm, oil.
18. Magneto or dynamo, oil.

Front Forks.—A typical front fork construction with the handle bars attached is shown in Figure 138. For ordinary riding the front forks of motor cycles are almost always equipped with some form of spring to absorb the road shocks. One construction is shown in Figure 139. The hub of the front wheel is carried at the forward end of the rocker bars seen at the bottom of the two forks. The weight of the motor cycle is carried by the fork toward the left or rear of the machine. This weight bears down upon the rear end of the rocker bar and would tend to force the rear of the bar downward. Downward movement of the rear end of the bar moves the forward fork in such a way as to compress the coiled spring. The spring is designed and mounted in such a way that the downward motion of the load-carrying fork is supported so that the recoil also is carried by the spring. A design in which the spring consists of two parts is shown in Figure 140, one of these parts serving as a load-carrier while the other is used as a recoil.

A front fork having two load-carrying springs, one on each side of the wheel and also two recoil springs carried in tubes with the load springs, is shown in Figure 141. The operation of this fork is similar to the one just described except that four separate springs are employed.

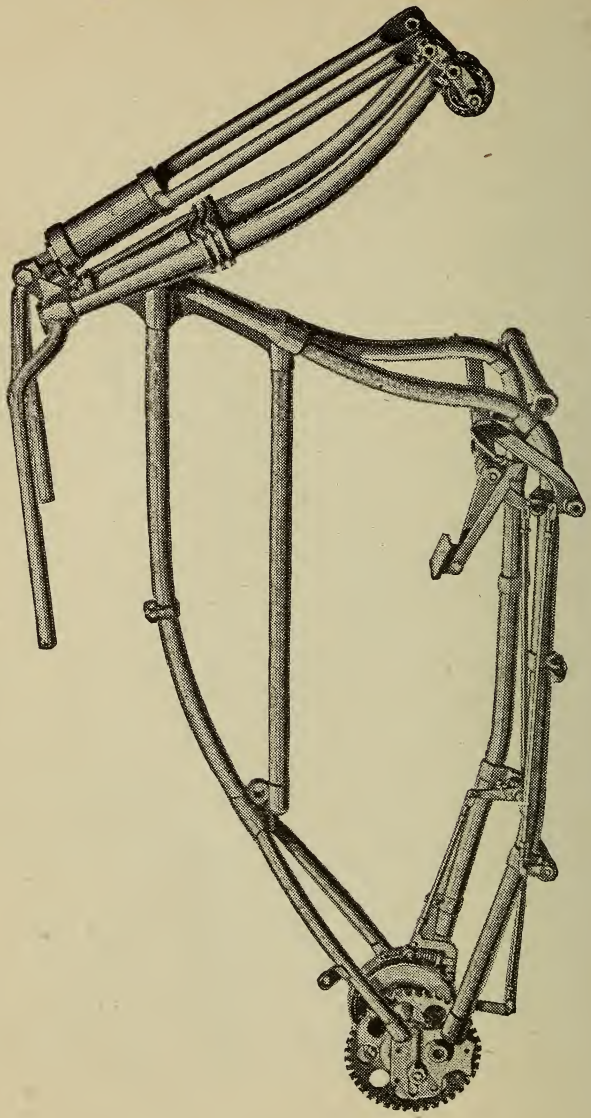

Figure 137.—Frame, Front Forks, Hubs, and Control Pedals (Henderson).

Care should always be exercised when removing any parts which hold coiled springs under compression for otherwise a sudden release of the spring may damage the mechanical parts or may even cause personal injury.

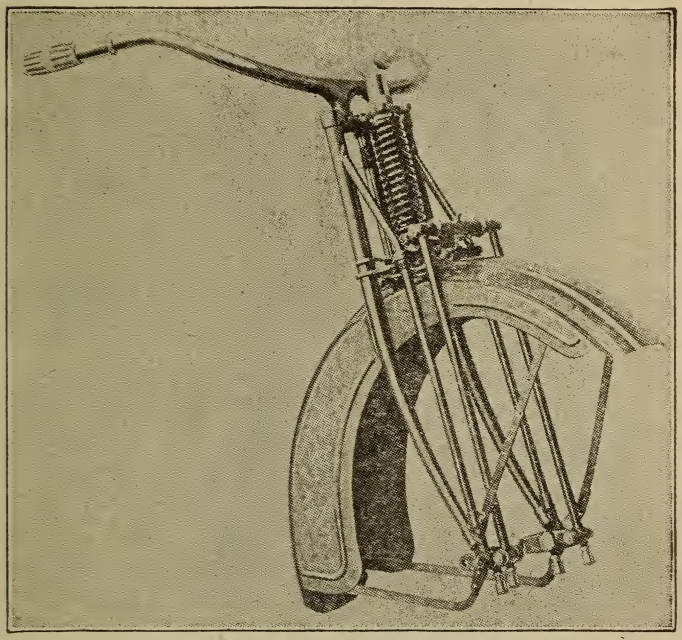

Figure 138.—Single Spring Front Fork (Harley-Davidson).

A front fork design using a compound leaf spring is shown in Figure 142. The weight of the motor cycle is attached to the rear end of this spring while the spring is supported at its front end by a frame member running down to the hub. With such a design,

additional recoil springs are not used because the friction between the spring leaves is sufficient to damp the rebound in much the same way as this friction acts in well designed automobile springs.

Rear Suspension.—A commonly used design of

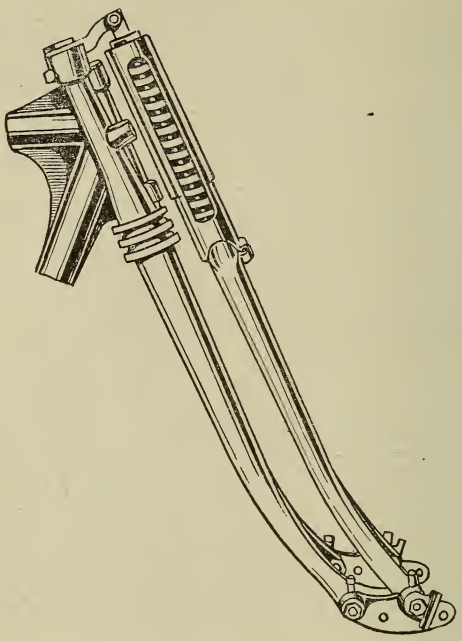

Figure 139.—Front Fork Construction (Reading Standard).

spring seat post is shown in Figure 143. A saddle is carried at the extreme left-hand end of the upper bar and the right-hand end of this bar is pivoted on the frame. Between the pivot and the seat, the bar is supported by a flange which is in turn carried by

a coil spring within the frame tube. Downward motion of the saddle is resisted by the upper spring while the recoil is met by the lower spring.

An application of this principle is illustrated in Figure 144. The tension of the springs in such a seat post should be made just stiff enough to prevent the

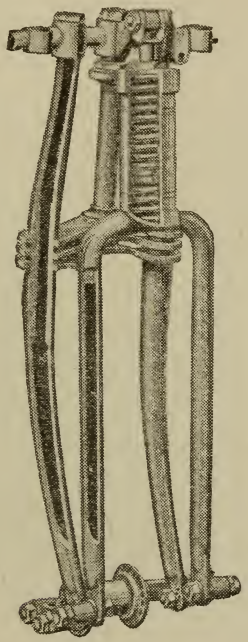

Figure 140.—Front Fork With Compound Spring (Excelsior).

post from striking bottom on a bump. This tension is adjusted by the nut *2* which is held by the jam nut *1*. The particular seat post illustrated is reached for adjustment by removing the pin *3*, and loosening

the nut *4* which clamps the tube at the point marked *5*.

A type of rear construction using leaf springs is shown in Figure 145. The weight of the motor cycle

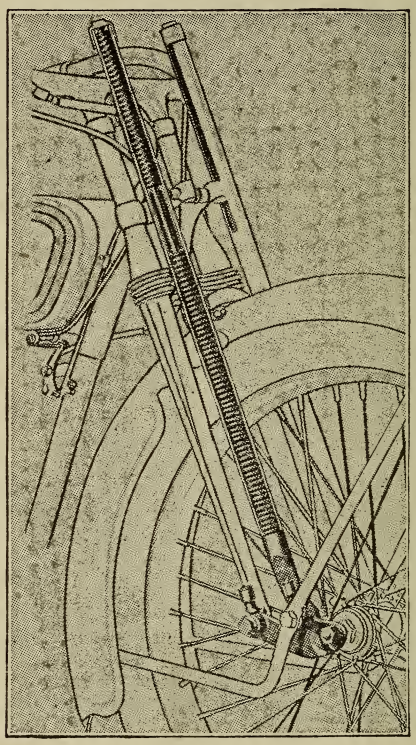

Figure 141.—Front Fork With Separate Shock and Recoil Springs (Harley-Davidson).

is carried at the thick end of the springs and the other end is supported by a framework carried over the rear wheel.

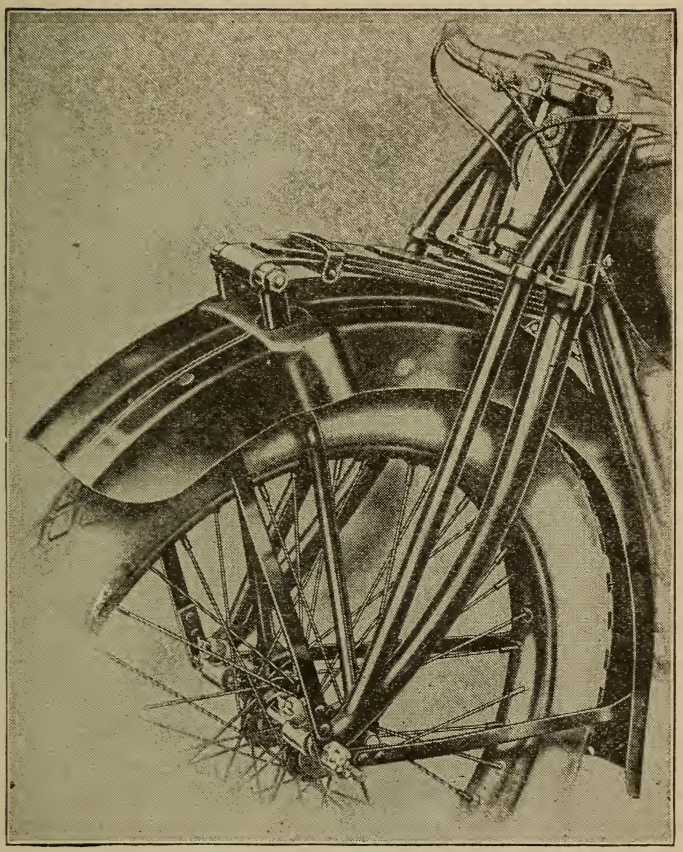

Figure 142.—Front Suspension With Leaf Spring (Indian).

FLEXIBLE WIRE CONTROLS

The parts of a Bowden wire control are shown in Figure 146. The wire member consists of two principal parts, one a closely coiled and practically incompressible housing which is called the outer member, and the other, a wire threaded through the housing and which is called the inner member. In motor cycle

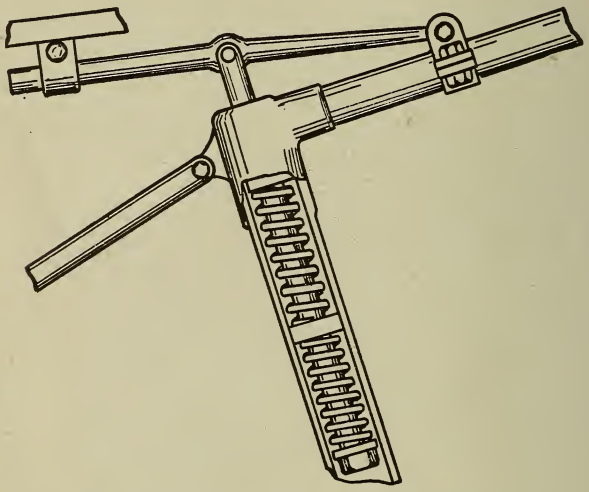

Figure 143.—Spring Seat Post Construction.

practice the outer member is anchored, usually at both ends, while the inner member is attached to a control lever at one of its ends and to the part to be operated at its other end. This wire control is used for operating the ignition and carburetor controls, the compression release, the brakes, and in some cases the clutch and transmission.

In handling this type of control, care should be used

to see that the inner member on leaving the end of the outer member is kept in an absolutely straight line

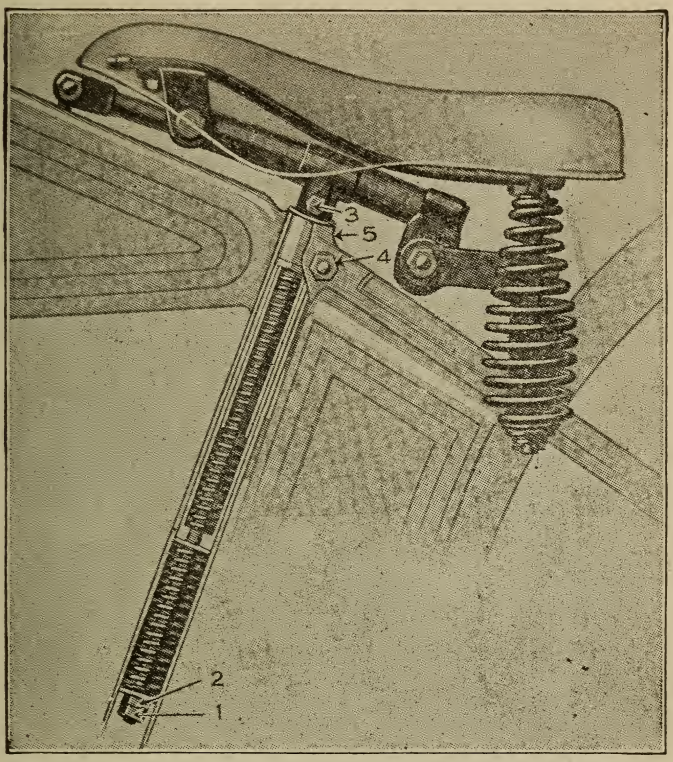

Figure 144.—Spring Seat Post Adjustments (Harley-Davidson).

for the remainder of its length because otherwise there will be rubbing and friction between the two parts. Whenever the wire is withdrawn from the housing, the wire should be covered with grease before the two parts are again assembled.

WHEELS AND HUBS

The construction of a front hub is shown in Figure 147. The hub flanges are drilled with counter-sunk

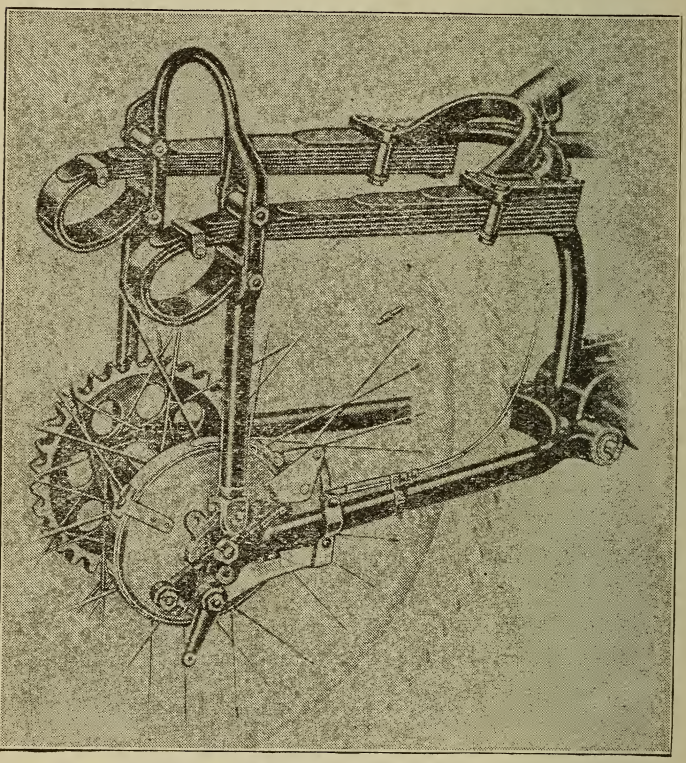

Figure 145.—Rear Suspension With Quarter Elliptic Springs (Indian).

holes which receive the spokes. The flanges and barrel are supported by ball bearings of the cup and cone type. The cup is carried in the hub barrel while the

cone is adjustable by being fitted onto a threaded central portion of the hub as shown in the illustration. Such bearings are properly adjusted when they are just tight enough so that the wheel will spin freely and will come to rest with the tire valve at the bottom. A correct adjustment will allow a very slight shake of the wheel.

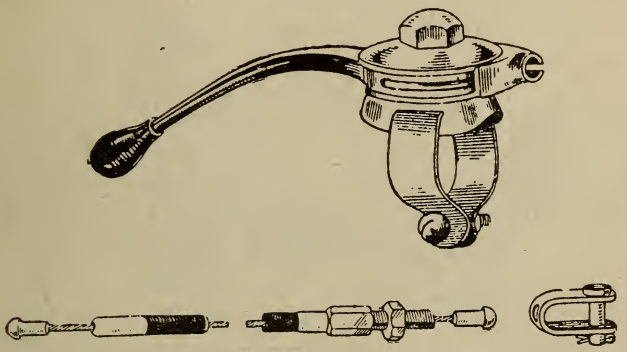

Figure 146.—Parts of Bowden Flexible Wire Control.

Cup and cone bearings are adjusted by loosening the lock nut and then turning the cone one way or the other, to loosen or tighten the bearing. The right-hand cone will usually have a right-hand thread, while the left-hand cone has a left-hand thread. By feeling of the wheel while turning the cone it may be quickly determined whether the bearing is being tightened or loosened. When the adjustment is thought to be correct the lock nut should be tightened and the adjustment again tested to make sure that tightening these nuts has not affected the bearing. Hubs are best lubricated with a light-bodied cup grease because oil will tend to work out past the packing washers.

The spokes in motor cycle wire wheels always have a tendency to loosen, this being especially true in the rear wheel. The rear wheel should be examined after the first two or three hundred miles driving and then each thousand miles thereafter. The front wheel and spokes should be examined three or four times a year. Loose spokes allow the rim to get out of line and this

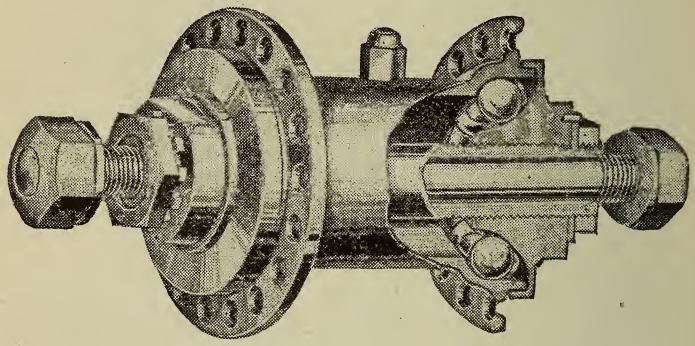

Figure 147.—Front Hub Construction (Excelsior).

causes wobbling, tire wear, and poor control. Riding with poorly inflated tires tends to loosen the spokes and this practice also damages the rims by allowing them to become dented and out of shape.

When examining the rim for alignment, the wheels should be slowly turned through a complete revolution and the rim should lie midway between the forks all the way around. It is best to have a rim trued up by an experienced mechanic because a novice will usually spend a great amount of time and will more often succeed in making matters worse than in remedying them. After a wheel is trued up by tightening or loosening the spokes, the spoke ends that

protrude on the tire side of the rim should be cut off flush with the nipples. If it is found that spokes continue to break in a certain wheel, it indicates that they have all been strained and damaged and the entire set should be replaced.

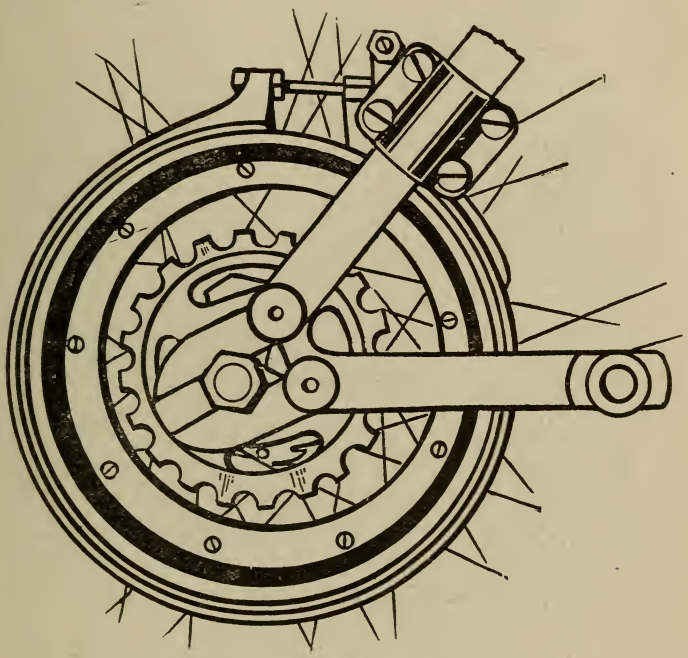

Figure 148.—Mounting of Rear Hub.

It is somewhat difficult to properly lace a set of spokes into a rim. Some of this difficulty, especially that found in positioning the spokes, may be overcome by tightly tying all of the spokes at each place where

two of them cross each other, before the old rim is removed. The nipples are then taken out and the entire set of spokes with the hub is removed from the rim. Nipples may then be stuck through the holes of the rim to be replaced and these nipples will be found to slant in different directions. The set of spokes may then be placed in position by seeing that each spoke slants in the same direction as a nipple into which it can be placed.

When preparing to lace the spokes into a wheel the spokes should first be assembled in the hub. It will be found that the head of each spoke will fit properly in the counter-sunk side of the hole and if this is watched the spokes cannot be wrongly placed. The work is started with eight spokes turned so that four of them have their heads up and so that the other four have their heads down. They are crossed so that the outside spokes will cross four others. If crossed in the wrong direction, the outside spokes will only cross three others.

The outside spokes must run in a direction opposite to that of the inside spokes on the same side of the wheel, but they will run in the same direction as the inside spokes on the opposite side of the wheel. These first outside spokes will then run in a direction opposite to the outside spokes on the opposite side of the wheel. Before the spokes are entered in the rim, the angle of the punch holes of the rim should be noted and when the spokes are properly lined up it will be found that they lie in the same direction as the rim holes. All the nipples must fit properly into the counter-sinks of the rim and all the spoke heads must fit properly into the counter-sinks of the hub flange when lying in the correct position.

The strength of a rear wheel may be increased and its alignment preserved by wiring the spokes together at the points where they cross one another. This practice may somewhat decrease the resiliency and easy riding qualities of the wheel.

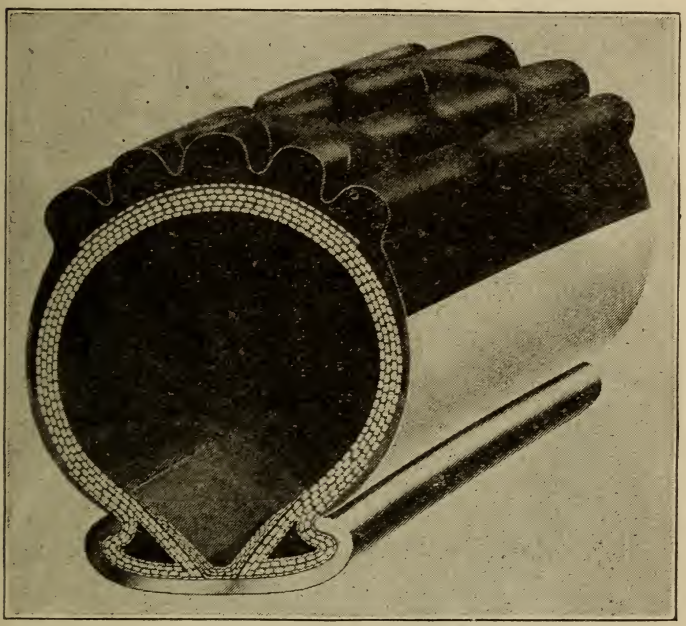

Figure 149.—Construction of Motor Cycle Tire Casing (Goodrich).

TIRES

The tire is described as to size by mentioning its sectional diameter which is the distance through the tire from left to right and by mentioning its over-all diameter which is the height from the road surface to

the extreme top of the tread. Motor cycle tires are made in sections of $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3 and $3\frac{1}{2}$ inches. The greatest number are in the 3 and $3\frac{1}{2}$ inch sizes. Overall diameters are 26, 27, 28 and 29 inches, most of them being either 26 or 28 inches.

Motor cycle tires are of the clincher type as shown in Figure 149. Such a tire is held in the channels of its rim by the shape of the bead. Inside of the casing shown in the illustration is placed the inner tube and between the beads of the casing is placed a strip called the flap, this flap serving to prevent direct contact between the inner tube and the rim to avoid pinching of the tube.

Motor cycle inner tubes may be made in either of two types. One is the endless tube similar to that used with automobile tires. The other is called a butt-end tube and is made in one long piece so that it may be inserted into the casing without taking the wheel from the frame.

As described by the Goodyear Tire & Rubber Company in their booklet, *The Story of the Tire,* there are two general methods of manufacturing motor cycle tires. In the core-and-mold construction, the tire is built up in plies of rubber-coated fabric, cut on the bias, the plies being stretched onto an iron core.

These tires are built of three or four plies. In building three-ply tires, after the first ply has been put on, the bead strips, which are made of a semi-hard rubber compound, are placed in position on the sides of the tire, then the second and third plies are pulled on and rolled down over these beads, after which a ply of tread gum is put onto the tire to cover it entirely on the outside. In four-ply tires two plies are put under the beads and two over.

On the larger sizes of motor cycle tires, a breaker strip coated with cushion rubber is placed between the last ply of fabric and the tread. This aids the union between tread rubber and fabric and distributes the shock of sudden bumps by providing an elastic cushion to spread the strain.

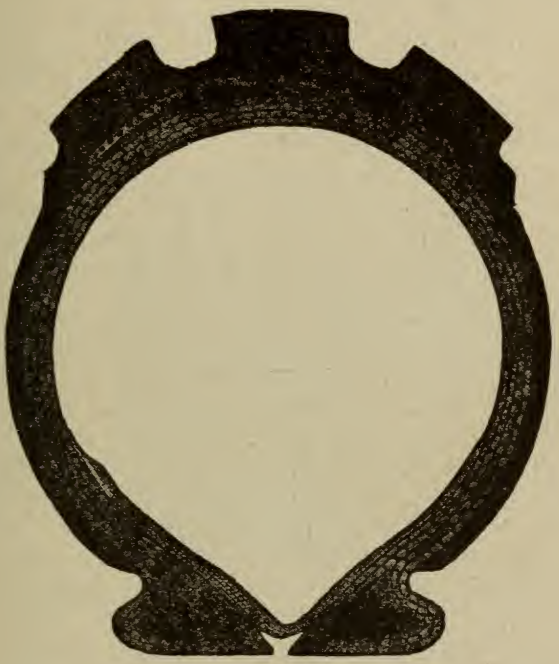

Figure 150.—Motor Cycle Tire Construction (Goodyear).

When the building of the tire is finished, and with the core still inside, it is placed into a mold. The mold is put into a heater press under hydraulic pressure and the tire is there vulcanized. After vulcaniza-

tion, the tire and core are removed from the mold and the tire pulled off the core.

In the second method a drum is used, the surface of which is turned to take the outside of the tire flattened out. In building a tire on such a drum, the procedure is exactly the reverse of the core method. First, the tread rubber is placed on the drum, next the outside ply, then the middle ply, then the beads are set in place and finally the inside plies. The tire is thus in the shape of a flat band with the inside part of the tire on the outside.

The tire is wrapped onto the drum with a long narrow strip of wet cloth under tension, and the whole is rolled into a vulcanizer similar to that used for curing bicycle tires. After curing, the wrapping is removed from the drum and the tire stripped off and turned right side out.

In many cases the tire is now finished and sent out in this shape. Some manufacturers take the tire in this shape and inflate it over an inner tube on a rim and put it back into the vulcanizer for a few minutes to set it into the proper shape. Others shape the tire by wrapping it down on a core, thus giving the tire the shape cure.

In Figure 151 the parts of a motor cycle tire are clearly shown. Number *1* indicates the plies of fabric which form the carcass; *2* shows where rubber gum is placed between the plies of fabric; *3* shows the layer of cushion stock between the plies of fabric and the carcass, also the breaker strip; *4* indicates the tread which is made of tough and resilient rubber; *5* indicates the side wall, and *6* indicates the beads which fit into the channels of the rim.

Tire Removal and Replacement.—If a tube is to

be removed or exposed for repair without taking the wheel from the frame, the casing should be lifted on the side which is away from the drive chain or belt so that the tube will not be pinched by the drive when the wheel is revolved. Many tires are marked "Apply This Side Last and Remove It First." When such an instruction appears it should be heeded.

After the tube has been repaired it should be carefully replaced in the casing and if of the butt-end type, especial care should be exercised to see that

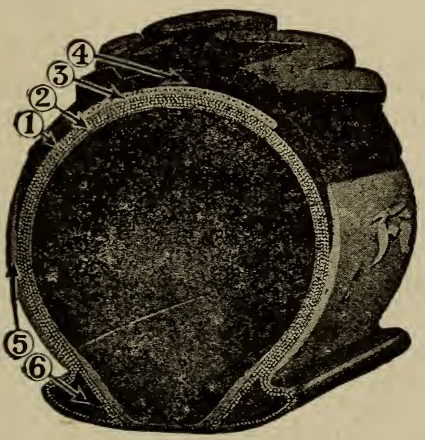

Figure 151.—Parts of a Motor Cycle Tire (Firestone).

the tube is not twisted for a twist will result in a blow out. The flap must be in good condition and carefully adjusted under the tube. After the casing bead is replaced the tire should be lightly inflated and the inside bead examined to make sure that no part of the inner tube has been pinched.

Tire Abuse.—The tread of the tire will be rapidly worn away if the wheel rims are out of true or if the wheels are out of line in the forks. Loose wheel bearings or bent forks will also result in quick tread wear. Too quick use of the brakes so that they slide the wheels, too quick acceleration in low gear, or high speed over rough roads with the resultant spinning of the drive wheel, will all result in great damage to the tires.

It may sometimes be found that oil from the exhaust is deposited on the outside of the casing and if this is found to be true, the oil should be wiped away with gasoline.

Tires are greatly abused by incorrect inflation. A $2\frac{3}{4}$ inch tire should be inflated to thirty-five pounds, a 3 inch tire to forty pounds, and a $3\frac{1}{2}$ inch to forty-five or fifty pounds.

Tire Care.—Inner tubes should always be the same nominal size as the size of the casing in which they are to be used. A three-inch tube should not be used in a two and one-half inch casing because the tube will be wrinkled and creased. Neither should a small tube be used in a large casing because the rubber of the inner tube will be stretched so far that its life will be shortened. Soapstone, mica or graphite are used to prevent the inner tube from sticking to the inside of the case when it remains in place for a long time.

It is poor economy to use an old inner tube or an inner tube that carries a great many patches inside of a new casing. Nothing is much harder on a casing than being run practically deflated, and an old tube always leaks at a fairly constant rate, even though the leak may be quite slow.

Before any attempt is made to put the casing on the rim, all rust, road dirt and other foreign matter should be removed from the metal parts with which the casing will come in contact.

When removing a tire preparatory to repairing a puncture the tube should be marked to show which side was toward the right or left. Then, with the tube taken out of the casing, it may be pumped up until the leak can be found and with the position of the leak known, that part of the casing may be given a very careful inspection.

Should a casing blow out on the road a temporary repair may be made with an inside boot, or rim-cut patch as it is often called. These patches are sometimes placed inside of the damaged portion of the casing without the use of any cement because they are to be removed as soon as a permanent repair can be made. If the casing is too old to be worth vulcanizing a semi-permanent job may be performed by cementing the blow-out boot into place.

If a blow out has caused a large hole in the fabric of the casing an emergency repair can often be made by using an outside boot fastened by straps, hooks or leather lacings. Such a boot may be applied after the inner tube has been replaced or repaired, and after some form of reinforcement has been placed between the tube and the casing at the point of damage.

In order to insure long life and freedom from trouble in the tires it is necessary that the rims be kept free from rust and from dents. With the casing removed, all parts of the rim which come in contact with the rubber should be thoroughly cleaned with a stiff wire brush or with emery cloth. Any dents or

bends should then be straightened, because these will cause chafing and eating away of part of the tire bead. After the rims are cleaned and put into proper shape the metal parts should be given a coating of some good rim paint.

CHAPTER IX

POWER ATTACHMENTS AND SIDE CARS

BRIGGS & STRATTON MOTOR WHEEL

The Briggs & Stratton unit consists of a four-cycle air-cooled engine attached to a driving wheel and fitted with the necessary accessories in ignition, carburetion and lubrication to form a complete power unit. This power unit is attached along side the rear wheel of an ordinary bicycle and the controls are carried to the bicycle handle-bars. The outfit then acts as a traction device and drives the bicycle. The general construction is shown in Figures 152 and 153.

One of the noticeable features of this power plant is found in the valve action. The inlet valve is of the automatic type. It is drawn open to admit the mixture by the suction of the piston descending on the inlet stroke. When the cylinder has become filled with gas and as the piston starts on its compression stroke, the inlet valve is closed with the assistance of a light coiled spring. The exhaust valve is of the mechanically operated type and is operated from a cam having four lobes. The camshaft runs at one-eighth of the speed of the crankshaft so that one lobe comes underneath the valve-lifter at each second revolution of the crankshaft. The valve action is therefore the same as found in any other type of four-cycle engine.

Lubrication is by a constant level circulating splash system. The lower part of the crankcase forms a reservoir from which oil is drawn by a plunger pump driven from an eccentric on the camshaft. The oil

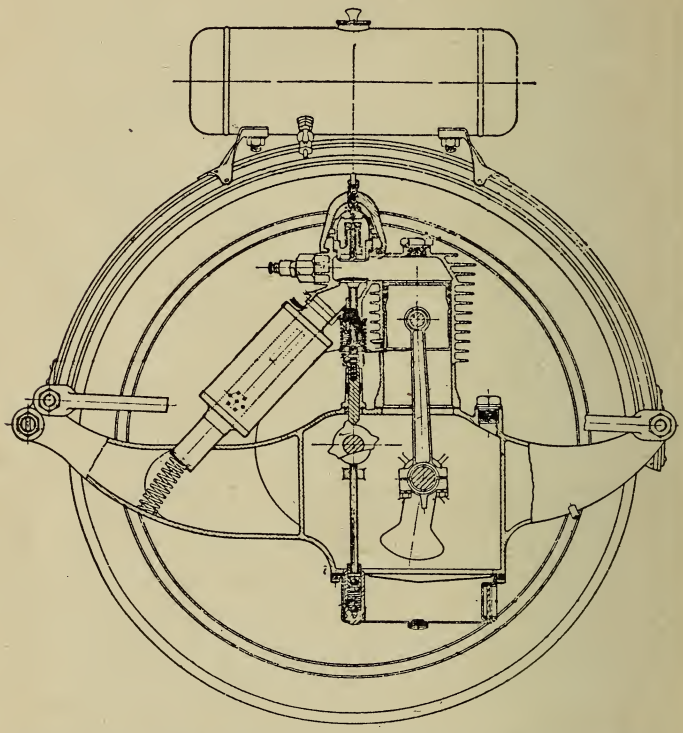

Figure 152.—Side Elevation of Briggs & Stratton Power Plant.

passes into the splash trough and its level is maintained by an overflow.

The Briggs & Stratton carburetor is shown in Figure 154. The carburetor includes a non-adjustable

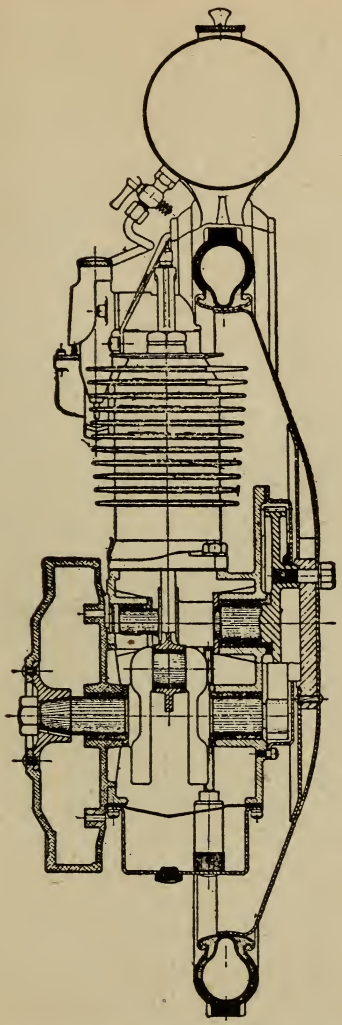

Figure 153.—End Section of Briggs & Stratton Power Plant.

nozzle consisting of four parts; the nozzle itself, a plug, a coil spring, and a fibre washer. The throttle valve is of the piston type.

The traction wheel is mounted on the end of the

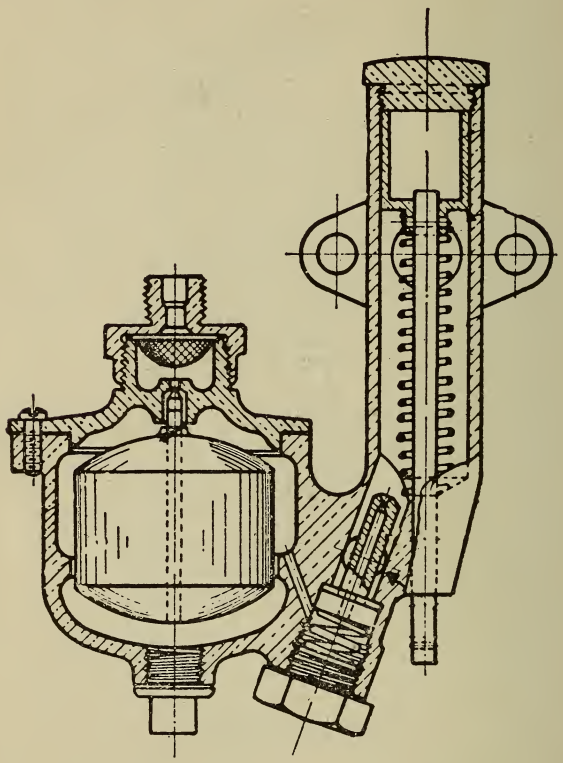

Figure 154.—Briggs & Stratton Carburetor.

engine cam shaft. In order to distribute the wear on the tire that is caused by the power impulses, the wheel should be removed at the end of each five hundred to one thousand miles and its position should

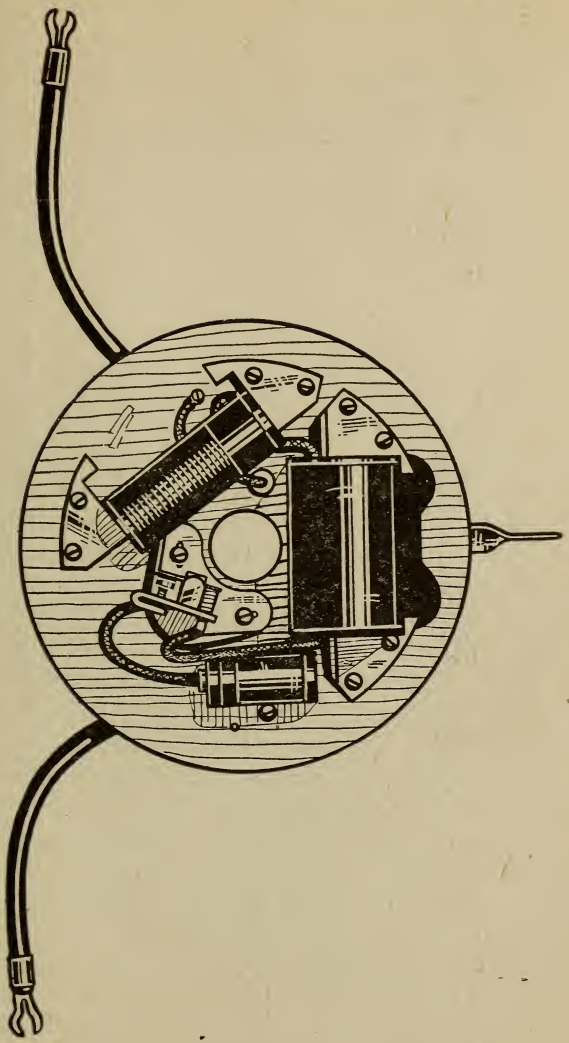

Figure 155.—Magneto Used on Johnson Power Attachment.

be changed by removing the bolts which hold the traction wheel and advancing one space forward so that power impulses affect other parts of the tire.

JOHNSON MOTOR WHEEL

The Johnson motor wheel unit includes a two-cylinder two-cycle horizontally-opposed engine carried above the rear wheel of a bicycle and driving the rear wheel through a chain which runs over a large sprocket attached to the wheel rim.

With this engine is used an unique type of magneto shown in Figure 155. The moving part of the magneto is the flywheel of the engine and contains the magnet, pole pieces and cam. The stationary part of the magneto is called the armature plate. It carries a large ignition coil and armature and a smaller lighting coil and armature, a condenser in a metal tube and the breaker. Two thick rubber-covered wires with metal clips are used for ignition. A thin wire coming from near the center of the armature plate is a lighting wire. The ignition and lighting systems are entirely independent of each other.

Electricity is generated for both the ignition and lighting currents by revolving the magnet around the coils and their armatures. At the moment the pole pieces on the magnet pass the armature, the cam in the flywheel pushes the breaker blade and opens the points of the breaker which causes a spark at the plugs and also creates current for lighting.

The breaker points should open one-sixty-fourth of an inch. By opening the small hole in the flywheel and turning the flywheel back and fourth, it may be seen whether the points are opening the correct dis-

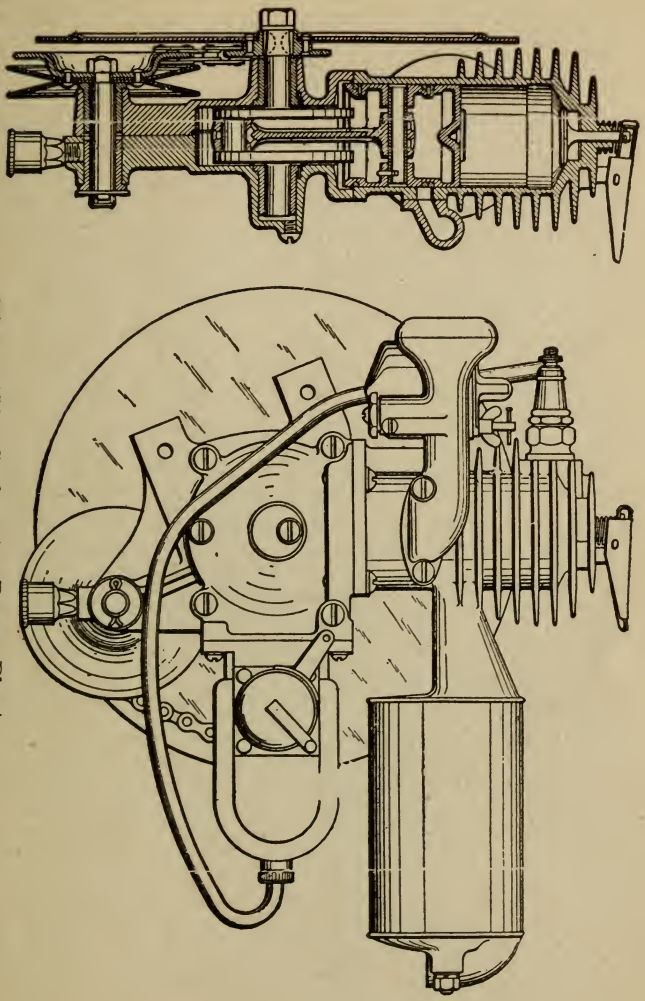

Figure 156.—Cyclemotor Power Plant.

tance. They may be adjusted with a magneto wrench through the inspection hole.

After the breaker points are adjusted to the correct distance, the timing may be adjusted. A timing line marked *S* is on the edge of the flywheel and a like mark is on the back of the armature plate. These two marks should be brought exactly opposite each other by turning the flywheel. While looking through

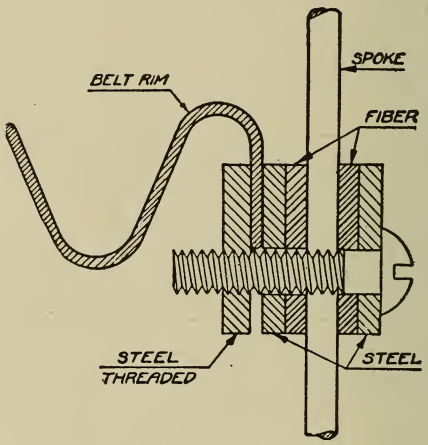

Figure 157.—Cyclemotor Belt Pulley Attachment.

the small hole in the flywheel, the flywheel may be turned back and forth, and it may be seen if the points of the breaker are just starting to open when the timing marks on the edge of the flywheel and the back of the armature plate are opposite. If they are not just opening at that time, the two screws holding the breaker plate are slightly loosened and the breaker plate is moved until the breaker points just start to open when the timing marks are opposite each other.

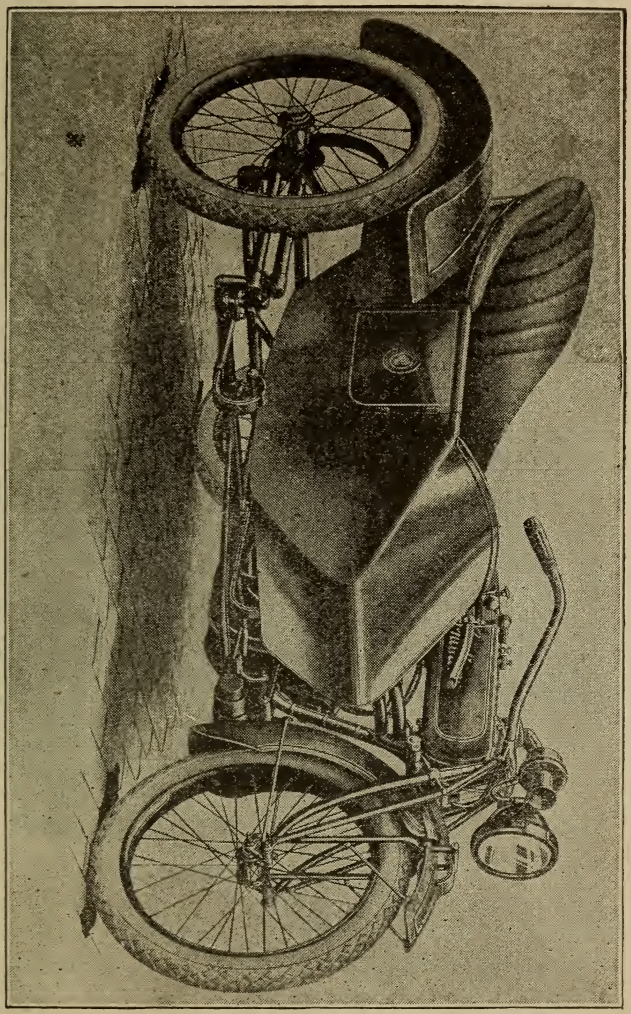

Figure 158.—Typical Side Car Construction (Indian).

The usual electric bicycle lamps may be used for both head and tail lights. If both head and tail lights are used, the bulb for the head light should be 2.8 volts and for the tail light 4 to 6 volts. If only one

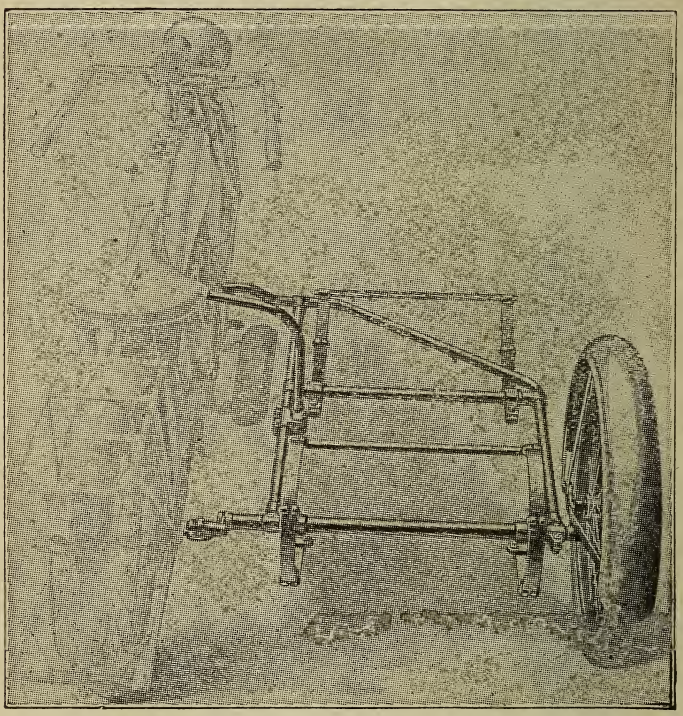

Figure 159.—Side Car Running Gear (National).

light is used, the bulb should be 2.8 volts. To connect the lamps with the lighting coil, the wires from both lamps are connected to the light wire which comes out of the magneto near the center. If double contact lamps are used, one lamp wire is grounded by

attaching it securely to a metal part. If electric lights are not used, the lighting wire from the magneto is twisted securely out of the way.

THE CYCLEMOTOR

In Figure 156 is shown the power plant of the Cyclemotor. This consists of a single-cylinder two-

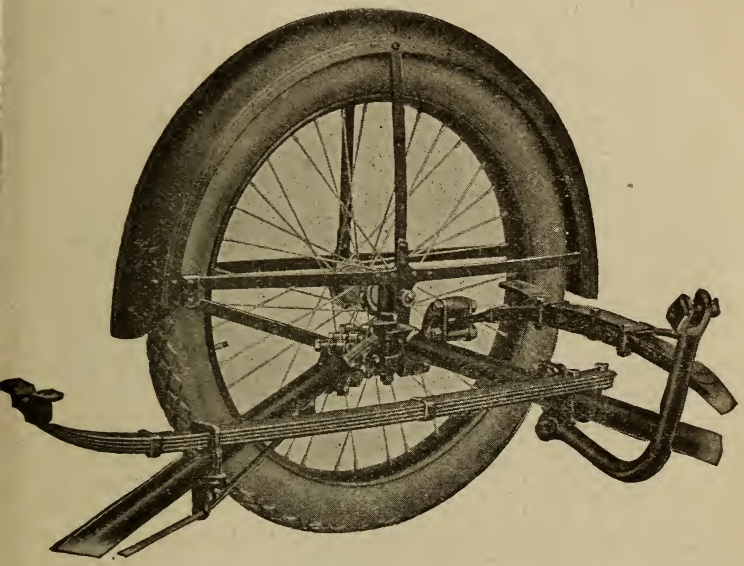

Figure 160.—Mounting of Side Car Wheel (Rogers).

cycle engine of one horsepower which is designed to reach speeds as high as three thousand revolutions a minute. The power plant is carried within the diamond of a bicycle frame. Power from the engine crankshaft is carried to a belt pulley through a chain

and this same chain serves to drive the magneto. From the belt pulley power is carried to the rear wheel through a V type leather belt.

SIDE CARS

Side cars for carrying passengers or merchandise may be fitted to any of the motor cycles in the heavy-

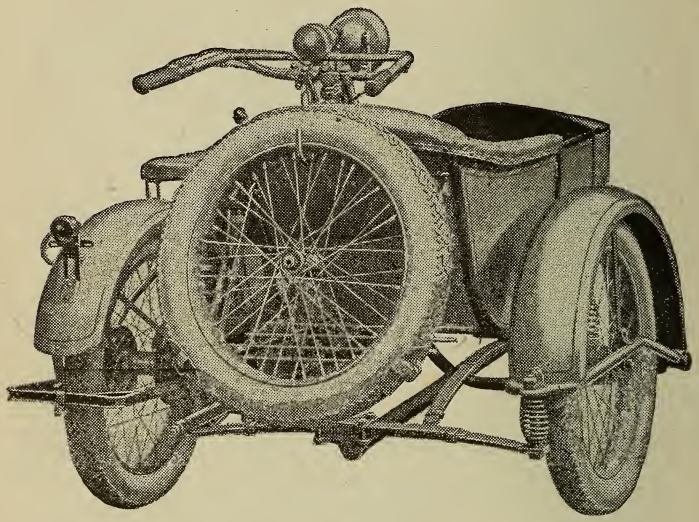

Figure 161.—Side Car Suspension (Excelsior).

weight class. In some cases the engine for a side car outfit has a larger compression space and therefore a lower compression pressure than the regular type. This makes the engine better able to handle hard pulling at low speeds, although it somewhat reduces the maximum speed available.

A motor cycle for use with a side car should have

a comparatively low gear in high speed, this ratio usually being at least five-to-one. With high geared machines there is considerable danger of overheating and a more or less serious lack of power.

It is necessary that a side car be properly aligned with the motor cycle and before attaching the side car, the frame, the forks and the wheels of the motor cycle should be carefully lined up.

When a side car is to be attached, a straight edge

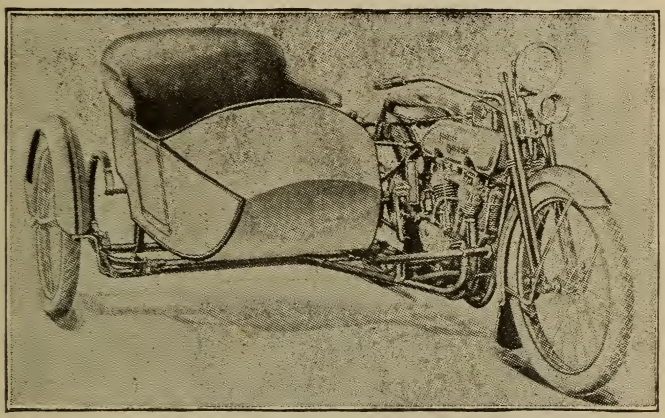

Figure 162.—Two-Passenger Side Car (Harley-Davidson).

should be laid along both wheels of the motor cycle and a similar straight edge should be laid along the side car wheel. While the motor cycle is practically upright, the side car should be adjusted until the straight edges are exactly parallel with each other. The side car should be so attached that the top of the side car wheel leans slightly away from the motor cycle or so that the top of the motor cycle wheel leans slightly away from the side car.

With the side car in proper alignment, tire wear will be reduced to a minimum and driving will be extremely easy. If the side car wheel leans toward the machine or the machine toward the side car, the motor cycle tires will wear on the right hand side instead of the center and on the side car the tire will wear on the left hand side. The steering will also be interfered with. With the side car leaning away

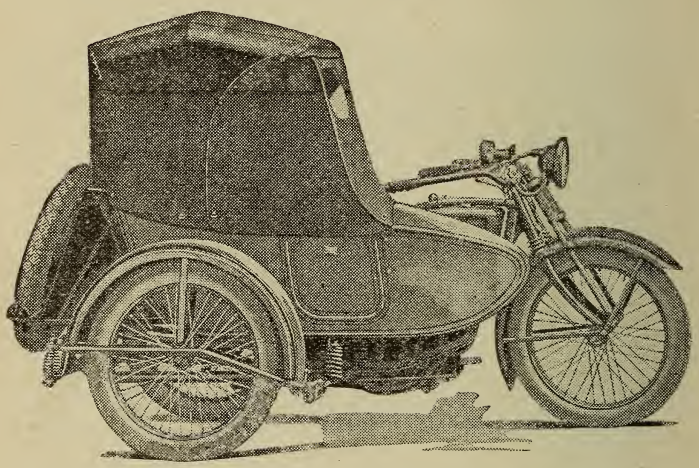

Figure 163.—Side Car With Top and Storm Front (Excelsior).

from the machine, the tires will be worn on the outside instead of in the center and their life materially shortened. In this position, the steering will also be affected and there will be a side-drag, most noticeable on high-crowned roads. With a side car properly aligned, the machine will travel straight ahead for one hundred feet or more on a level road when running at moderate speed and without guidance.

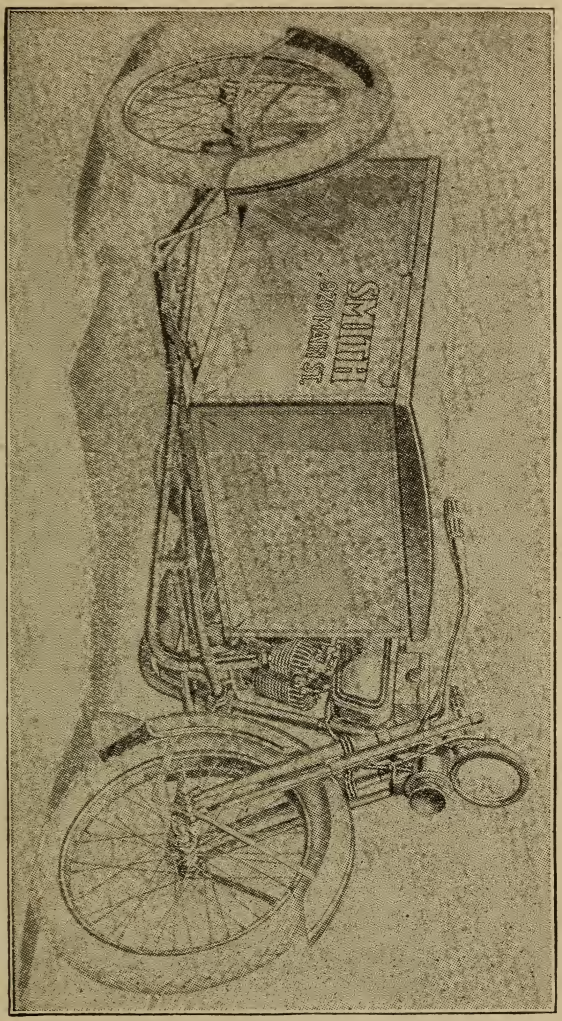

Figure 164.—Package Car (Harley-Davidson).

The side car fastenings, the ball and socket joints, and all nuts and bolts should be kept properly adjusted and tightened. Ball and socket joints should be lubricated at frequent intervals because otherwise they will rust solid and become bent or broken.

A machine carrying a side car should not be overloaded. It has been decided that five hundred pounds is the normal carrying capacity of the motor cycle

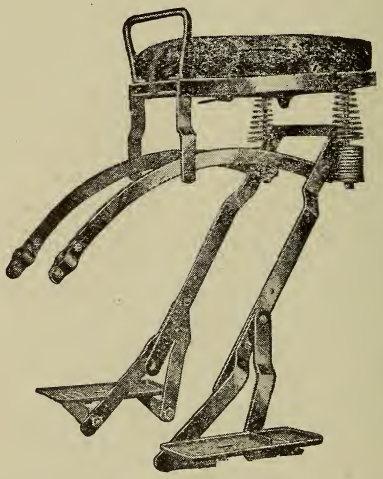

Figure 165.—Tandem Attachment (Fentress-Newton).

and side car combined. This would mean that the weight of the driver combined with the weight of the side car and its passenger or passengers should not exceed five hundred pounds. This limit applies to ordinary riding conditions but in driving over very rough or hilly roads the weight should be reduced. While a motor cycle and a side car will pull a heavier load than that mentioned, it will be done only at the

expense of mechanical life and of high maintenance.

In driving a side car around a right-hand corner the clutch should be disengaged and should be allowed to engage again at the turn. The motor cycle will turn around the side car wheel. In turning to the left, the corner should be approached with the

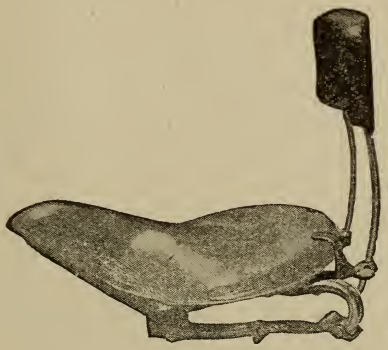

Figure 166.—Back Rest Attached to Saddle (Fentress-Newton).

clutch disengaged and it should be kept disengaged until the turn has been completed. If this method is not followed the side car will tend to skid to the right when making a left-hand turn and will tend to rise from the ground when making a right-hand turn.

CHAPTER X

MOTOR CYCLE REPAIRS

Because of the extreme accuracy of workmanship and the close limits within which parts are fitted and adjusted, it is not advisable for anyone except an experienced mechanic to make anything other than minor repairs and service adjustments. It has already been mentioned that the motor cycle is a finer piece of mechanism than the average automobile and for this reason, while a motor cycle mechanic would do good work on an automobile, it does not follow that an automobile repair man would always do good work on a motor cycle.

The brief instructions given in the following pages assume that the one doing the work has a knowledge of general shop practice and is familiar with the proper use of ordinary shop tools and equipment. The information that is given is intended more as a series of cautions applying especially to motor cycle work than as a series of instructions which may be followed by a novice. To give a complete explanation of good motor cycle repairing would require that a treatise on shop work be included.

While most of the following material applies equally well to any type of motor cycle, the greatest attention has been given to work involved with handling the twin-cylinder, four-cycle. V type engine working in connection with a clutch and gear-set

through the usual forms of drive. This will of course allow the reader to handle two-cycle machines, single-cylinder machines, and machines without gear-sets, because those variations in practice are secured by omitting some of the parts of the more complicated heavy-weight outfit.

Good repair work in any field can be done only if the workman has access to good tools of the necessary variety. Except for a few running adjustments very little can be done with the tool kit furnished with the motor cycle. A mechanic's outfit should include a complete set of end wrenches and a fairly good selection of the commonly used sizes of socket wrenches. In many cases it will be desirable to secure special wrenches for fitting some of the less accessible bolts and nuts and also special wrenches for handling some types of hubs as well as for electrical devices.

Some of the following work will call for micrometers, both outside and inside, with fittings that allow them to measure work between three and four inches in diameter. It will also be necessary to have thickness gages, expansion reamers, gear pullers, copper hammers, and such machine shop tools as are generally available where work of this nature is to be handled.

CYLINDERS

When making ready to remove the cylinders from the crankcase it is of course necessary to disconnect practically all of the fastenings which attach to the cylinders. Especial care will be required in removing the exhaust pipe nuts because if they bind and are jerked loose with a large wrench, breakage of the cylinder casting may result. These nuts should be

soaked with kerosene for some little time before they are to be removed. While the wrench is applied and some strain put upon it, the nut should be tapped with a hammer. It may sometimes be necessary to run the engine in order to warm the parts before this connection can be taken apart.

The pistons should be brought to the bottom of their strokes before the cylinder is lifted off. The cylinder casting can then be raised while carefully rocking it or while slightly turning the drive sprocket so that the piston slides out easily.

When the cylinder is to be replaced it should be seen that the gaskets between the cylinder flange and the crankcase are unbroken. If they have been jammed or torn, new gaskets should be fitted. Should the engine have been fitted with plates between the cylinder and crankcase in order to reduce the compression pressure, a gasket should be put above and another below these plates.

After the cylinder has been removed it can be examined for the condition of the inside surface. If in good shape the cylinder walls will be found perfectly smooth and there will be no scratches, burned spots, or score marks. If the machine is comparatively new some of the marks of the grinder may still be visible.

If it is found that the cylinder is only slightly scored it may be put into fair shape by lapping, but if the score marks are at all deep, that is, if the marks are four or five thousandths of an inch below the surface, the cylinders should be reground. If the cylinders have previously been reground and again show deep score marks they will have to be replaced with new ones.

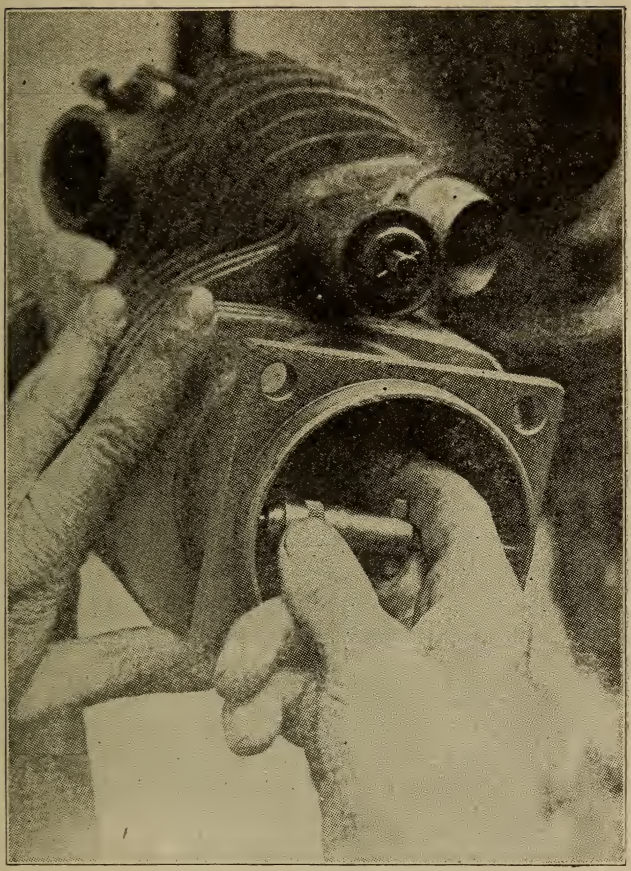

Figure 167.—Measuring Cylinder Bore With Inside Micrometer. (Courtesy of Harley-Davidson Motor Co.)

In order to measure the wear in the bore of the cylinder it will be necessary to use an inside micrometer as shown in Figure 167. The bore cannot be accurately measured with ordinary calipers or even with a gage, because it will be found that the wear has caused the cylinder to become larger at the upper end than at the lower. When calipering the cylinder bore measure it at several points between top and bottom and also try the micrometer at different angles in order to determine whether or not the cylinder is out of round.

Carbon Removal.—While the cylinders are off the engine the collections of carbon can be removed from all points inside the combustion space by means of specially formed scrapers. At this time the carbon can also be removed from the top of the piston, from inside of the piston, and from the piston-ring grooves. This cleaning should be performed once in each three or four thousand miles running and in no case should it be delayed for over a year. It is seldom, if ever, safe to burn the carbon out of motor cycle cylinders with oxygen as is a general practice with automobile engines.

It will be found in a number of cases that the cylinder head is separate from the barrel and held in place by studs or bolts. This practice is followed more as a measure to allow good machining inside a cylinder than as a means of allowing ready access to the combustion space. It will usually be best to handle all types of cylinders as if they were made in one piece, that is, remove them from the crankcase when the carbon is to be cleaned out.

The frequency with which it is necessary to remove the carbon depends in great measure on the oil feed

because too much oil will invariably result in considerable deposits of soot which are injurious in that they cause more rapid wear of the piston and cylinder walls.

The necessity for carbon removal can be postponed by injecting kerosene into the combustion space about once in each seven hundred and fifty to one thousand miles of running. While the engine is still hot from running, the spark plugs can be removed or the priming cups may be used to inject a liberal quantity of kerosene into each cylinder of the engine. If the work is to be properly done the oil line should be disconnected from the crankcase and a supply of kerosene placed at this point also. With the spark plug wires still removed the engine should be rapidly cranked so that all of the parts are washed clean. The drain plug in the bottom of the crankcase can then be removed and the kerosene drained away, the plug replaced and normal supply of oil put into the case. Again crank the engine a few times so that the oil is distributed, connect the spark plug wires and the machine is ready for operation.

When the carbon is removed from the engine it would be advisable to inspect the muffler and exhaust pipe because there may be a considerable loss of power due to the accumulation of carbon that forms in these parts.

PISTONS AND PISTON PINS

When the pistons are exposed all of their carbon should be removed, the rings should be taken out and their grooves should be cleaned. It will then be possible to determine whether the pistons show excessive

wear or whether they are scored. If work is to be done on the piston itself or on the connecting rod or its bearings, the pistons will be removed by taking

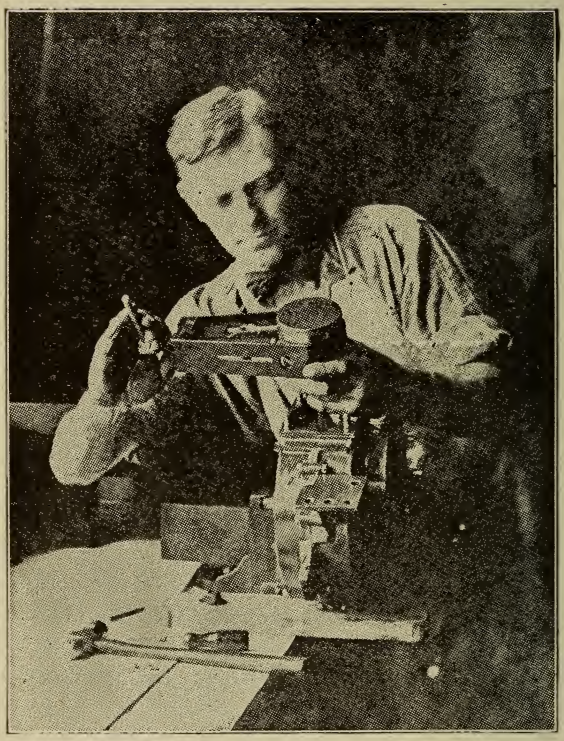

Figure 168.—Extracting Piston Pin. (Courtesy of Harley-Davidson Motor Co.)

out the piston pins but unless such work is necessary it will be best to allow the piston to remain attached to the rod. If the engine has more than one cylinder

the pistons should be carefully marked as to their position in the engine because it very seldom will be found that a piston from one cylinder will make a proper fit in any other cylinder.

The piston pin should be removed and replaced by the use of some such tool as shown in Figure 168. This tool is designed to give the walls of the piston proper support while the pin is forced out of or into its place by means of a screw. Piston pins are often handled by driving them with a punch and hammer but such a practice will almost always throw the connecting rod out of line and will make the piston itself very much out of round. Regardless of the method used in handling the pins it should be borne in mind that the piston is somewhat delicate and may be broken quite easily by the application of too much force.

If the engine is to be made quiet the pistons must be a good fit in the cylinders. If the pistons are a loose fit they will slap, while if they are too tight they will cause a tapping noise due to the pistons sticking at the top and again at the bottom of the stroke so that the slack in the connecting rods is taken up at each of these positions. The micrometer should be used as in Figure 169 to measure the diameter of the piston at its lower end about one-half inch from the bottom. Measurements should be taken at several positions around the cylinder so that it can be noted whether the walls are out of round. If the piston is found to be more than ten thousandths of an inch smaller than the upper end of the cylinder bore, it will be necessary to fit a new over-size piston. If it has been found when measuring the cylinder, that the upper part of its bore is larger than the lower

end, it will be necessary to regrind the cylinder and to fit over-size pistons.

In selecting a new piston, the small diameter of the cylinder should be found first and a piston should be used whose large diameter is very close to three

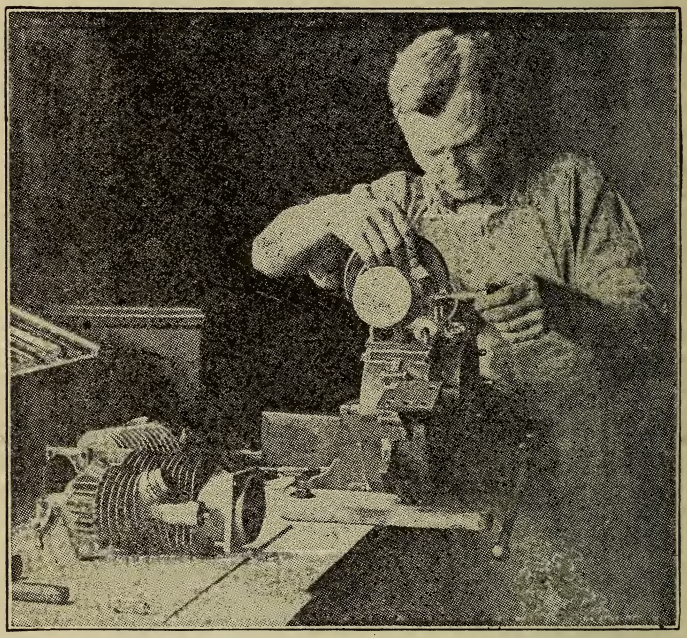

Figure 169.—Measuring Piston Diameter With Outside Micrometer. (Courtesy of Harley-Davidson Motor Co.)

thousandths of an inch smaller than the cylinder diameter. With such a fit, lapping will not be necessary. Should the fit be made much closer than three thousandths of an inch, the new piston with its rings will have to be lapped into the cylinder, which is a shop operation.

The piston pin should be a running fit in its bushings and with the pin in place the piston should have about one-sixteenth of an inch end play along the pin. Should a new piston pin bushing be fitted it will be necessary to ream it with very light cuts as in

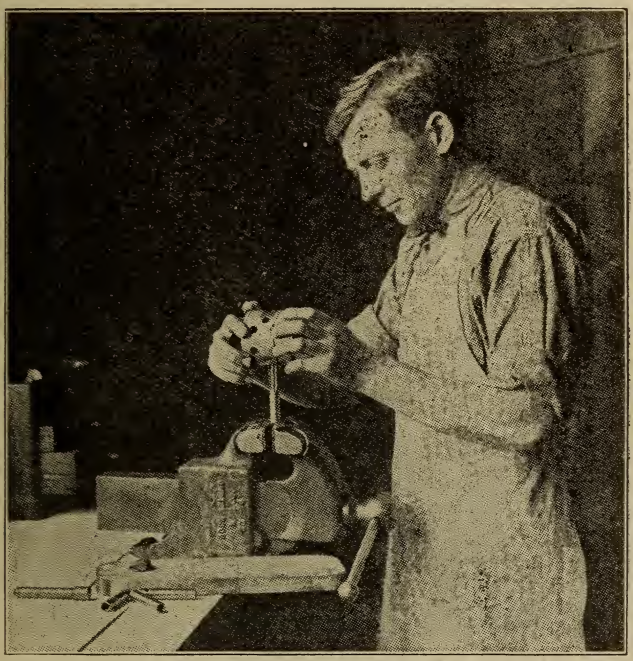

Figure 170.—Reaming Piston Pin Bushing. (Courtesy of Harley-Davidson Motor Co.)

Figure 170. The bushing should be reamed only large enough so that the weight of the piston will turn the parts when the piston and connecting rod are held horizontally. Should an over-size piston pin have been fitted to the bushing it will be necessary to ream

the piston openings to take this over-size pin, when the construction is such that the pin is stationary in the piston.

After the piston and pin have been assembled, the flywheels should be turned until the crank pin is at its lowermost point. The pistons can then be examined to see that they are approximately centered with the cylinder opening into the crankcase. It must be possible for the piston to take an absolutely central position in this opening without causing the bosses in the piston walls to rub against the piston pin bushing or without allowing the connecting rod to strike bushings carried in the pistons. If the pistons cannot be centered in these openings, and if it is known that the connecting rods are in line, it will be necessary to remove a little metal from either side of the piston pin bushings or else it may be possible to move the bushings a little in the direction that will allow more clearance. The pistons should never be brought to a center by putting two offset bends in the connecting rod.

After the pistons have been attached to the connecting rods and centered with the crankcase openings, they should be measured for roundness. The outside micrometer should be used to take measurements at several points around the lower end of the piston walls. If the piston is found to have high spots these may be removed by carefully striking them with a hammer handle or piece of wood. In some cases the piston can be made round by the use of a clamp. Failure to make the pistons almost absolutely cylindrical will be very liable to cause overheating and a loss of power. After the pistons have been made round they should be handled with care and should

not be allowed to strike the connecting rod or crankcase.

Squaring the Pistons.—The axis of a piston must be absolutely true with the axis of its cylinder because otherwise the piston will be tipped so that there will

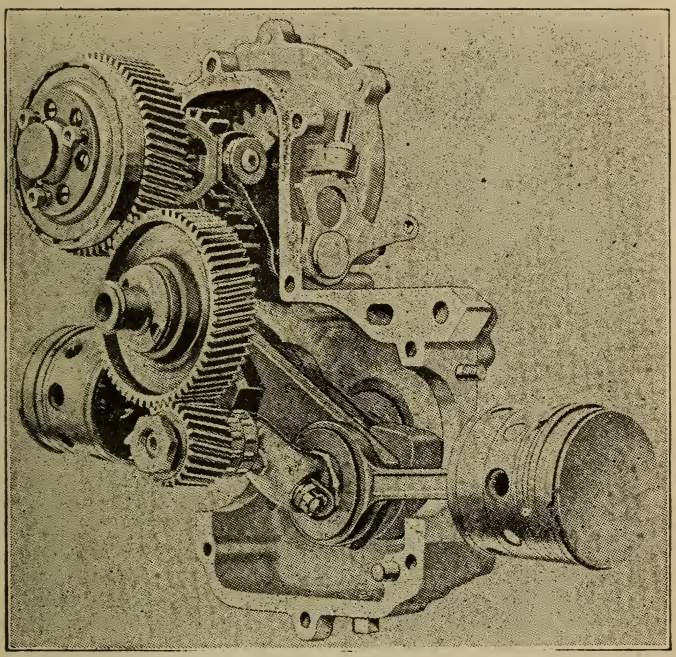

Figure 171.—Connecting Rod Construction of Twin-Cylinder Opposed Engine (Harley-Davidson).

be a considerable loss of power and more wear at one point on the piston than at other points.

The pistons are tested for this condition by seeing that they are square with the finished surface of the

crankcase against which the cylinder flange fastens. Misalignment of this nature is sometimes found by using two steel squares with one of their legs resting on the crankcase while the other is laid along the piston wall.

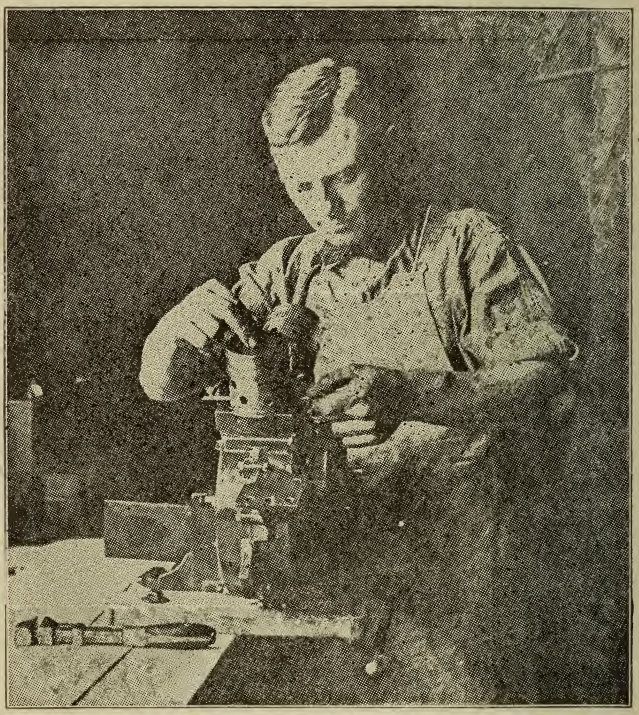

Figure 172.—Squaring Pistons With Surface Plate. (Courtesy of Harley-Davidson Motor Co.)

The more generally used method of testing the clearance of the pistons is to check them directly against the crankcase surface by the use of a squaring

plate as shown in Figure 172. This plate has its top and bottom surfaces perfectly parallel with each other and it is provided with an opening through which the connecting rod can pass. With the plate resting on the crankcase the lower end of the piston is brought down against the top of the plate. If the piston is found to bear evenly on both sides, it is square. The contact of the piston with the plate can be tested by placing very thin pieces of paper at opposite points, when it should be just as difficult to draw the paper away from one side as from the other.

The pistons should be tested for squareness first with the crank pin in its forward position and then with this pin toward the rear. Should it be found that one side of the piston does not rest on the plate with the crank pin forward, while the opposite side of the piston does not rest on the plate with the crank pin at the rear, it indicates that the connecting rod is twisted. If the failure to touch the plate is found to be on the same side of the piston regardless of the position of the crank pin, it indicates that the connecting rod is bent to one side or the other, but not twisted.

The pistons are made square by either bending or twisting, or by both bending and twisting the connecting rod as shown in Figure 173. This work is continued until both sides of the piston rest squarely on the plate.

PISTON RINGS

The piston rings should be examined to see that they have a full bearing against the cylinder walls all the way around the outside of the ring. Should

some points be found burned or scored the ring should be replaced with a new one. The rings are subjected to a great deal of heat and it may be found that some

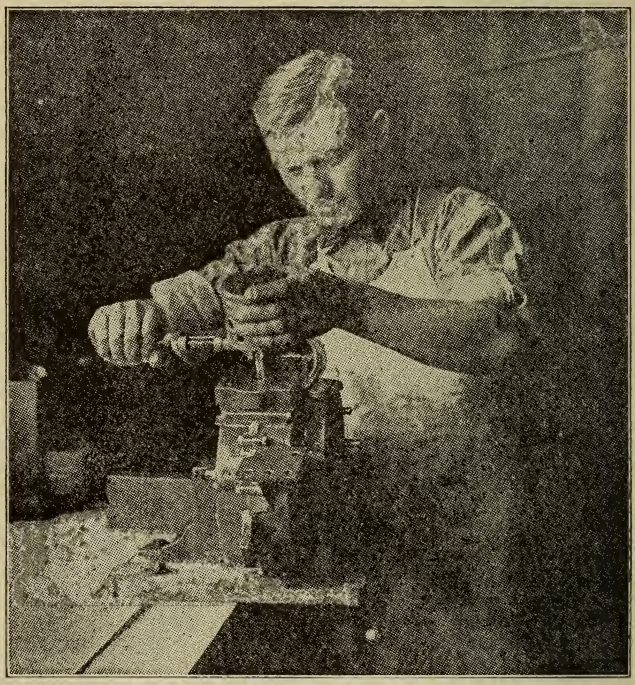

Figure 173.—Truing Connecting Rods. (Courtesy of Harley-Davidson Motor Co.)

of them, especially near the top, will have lost their resiliency so that they can no longer make a gas-tight fit.

The gap between the ends of the ring is for the purpose of allowing expansion under heat and for

allowing the ring to follow the variations in the cylinder bore. This gap can be measured by removing the ring from the piston and placing the ring squarely into its cylinder. If the gap is more than five-hundredths of an inch, it will allow a serious loss of compression. The proper gap for a new ring is about twenty-thousandths of an inch.

It may be necessary to file away some metal from the ends of the ring in order to secure the correct opening, but if the ring is originally of too large diameter and the ends are filed away in order to allow it to enter the cylinder, the face of the ring will not bear against the cylinder walls and it will be impossible to make a proper fit. After the ends of the ring have been filed they should be pressed together to make sure that they meet at all points, in other words, to make sure that the filing was properly done.

The rings should be tested for their fit in the piston grooves and there should be only the slightest freedom between the top and bottom of the ring and the top and bottom of the groove. If it is known that a ring is of the correct width and it still shows considerable looseness in the groove, it indicates that the grooves are worn and it will be necessary to replace the piston. It is assumed that the ring grooves have been carefully cleaned of all carbon before any attempt is made at fitting.

When it comes time to replace the cylinder over the piston with the rings in place, the gaps in the several rings should be placed at widely separated positions around the cylinder walls. Care must be used in dropping the cylinder into place that the rings are not jammed and broken.

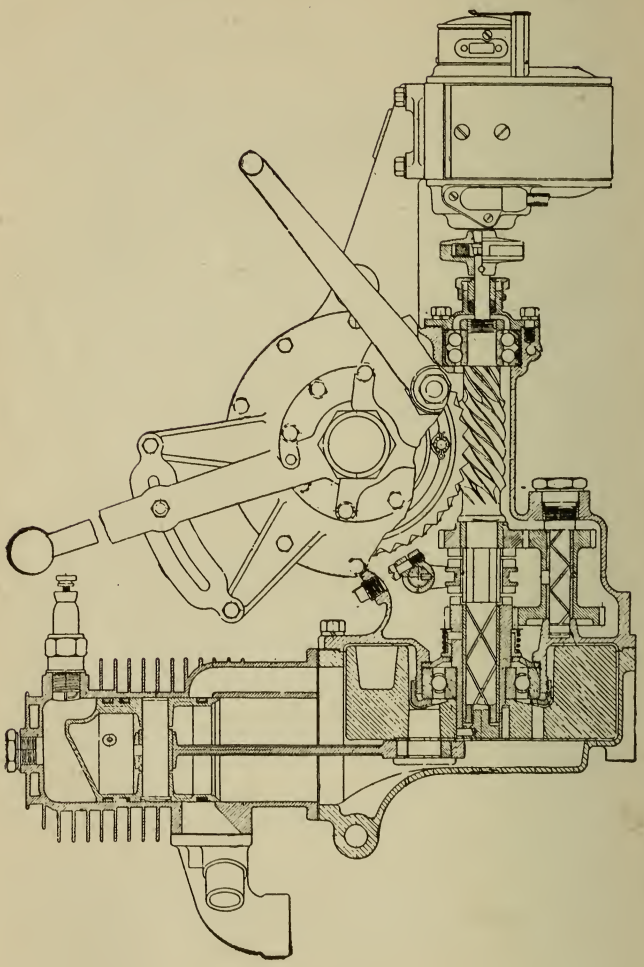

Figure 174.—Connecting Rod and Flywheel Construction (Cleveland).

ROLLER BEARINGS

Roller bearings are quite generally used at the lower end of the connecting rods in motor cycle engines. This type of bearing is also frequently used for one or both of the bearings in the crankcase which support the flywheels, as in Figure 175.

While the roller bearings should be examined when the engine is being taken apart for any reason, their adjustment should not be disturbed unless it is really necessary. The fit of the roller bearing at the lower end of the connecting rod can be determined by noting the up and down play of the rod while the crank pin is at its upper position and while the rod is being held straight up. If any up and down play can be felt with this movement, the bearings should be tightened. The fit of the roller bearing may also be tested by the side play of the upper end of the connecting rod.

Roller bearings of this type are generally refitted by substituting over-size rollers for those that have become worn. While this is true for the type of bearing in which the rollers may be easily inserted or withdrawn, it may sometimes be necessary to renew other parts of the bearing in addition to the rollers. Whether the work is done by fitting new rollers or by renewing the complete bearing, the final fit should be such that there is no perceptible play while the parts can still be turned around each other with perfect freedom.

FLYWHEELS

In fitting a tapered crank pin into a pair of flywheels, the parts must be drawn very tightly to-

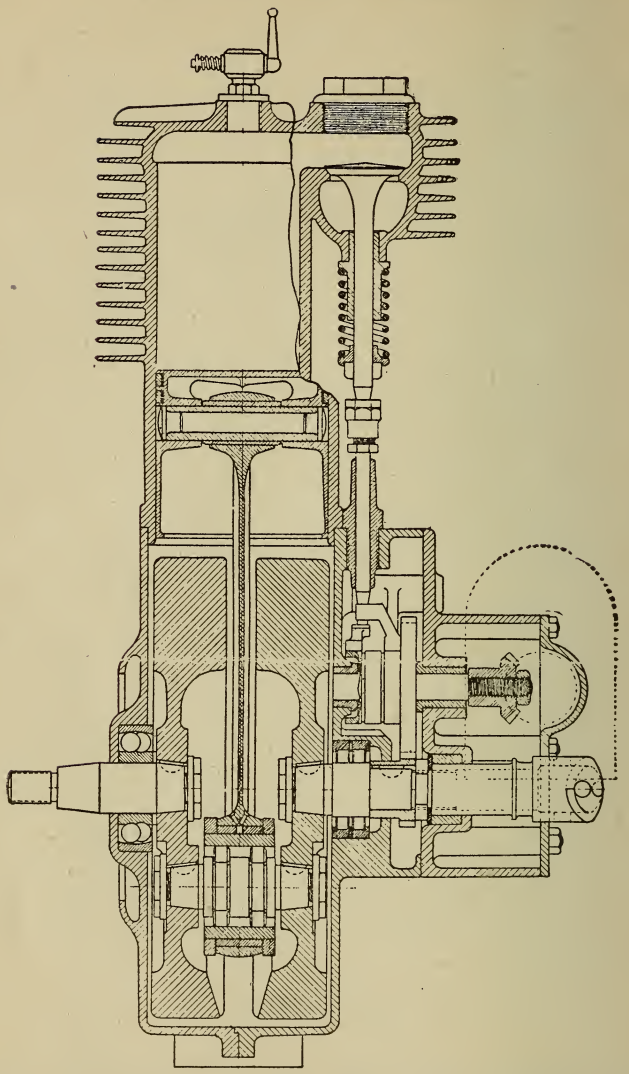

Figure 175.—Connecting Rod With Roller Bearings and Crankshaft With Roller Bearings and Ball Bearing (Precision).

gether. Should it be found that the connecting rods have no end play, but are cramped when the crank pin is tightly secured, it may be necessary to use a new pin or to change the fitting of the connecting rod bearing. In some cases this trouble may be caused by the taper holes in the flywheels being too large.

Whenever a key is used in connection with tapered shaft fittings, the key should have a bearing along its sides in both the key-ways, but it should not have a bearing in the bottom of both key-ways because this would prevent the tapers from making a correct fit. The key itself is seldom depended on to carry the drive, for this work can better be done by the friction of the tightly drawn tapers.

After the crank pin is fitted in the flywheels it is necessary to bring the two opposite flywheel shafts or crankshafts into exact line with each other. It is not necessary to true the rims of the flywheels or to true the faces of the flywheels, but it is necessary to true the shafts. The work can be correctly handled by mounting the flywheel and shaft assembly between centers made for this purpose as in Figure 176 or between the centers of a lathe. Indicators of the type shown can be placed in contact with each of the shafts so that when the assembly is turned, the indicators will show any misalignment. If standard lathe indicators are used in place of the kind illustrated, it will be best to lay a piece of clean white paper underneath the work and then to sight between the indicators and the shafts while the flywheels are turned.

When the high spots are located the shafts are turned until these spots are uppermost and then with the copper hammer the flywheel attached to the shaft

being straightened is struck squarely on top. If the flywheel is of the spoked type it should not be struck between two spokes and if the high point comes in such a position the wheels should be struck at two places directly over the spokes which are at each side of the high point. It is best to true both the shafts

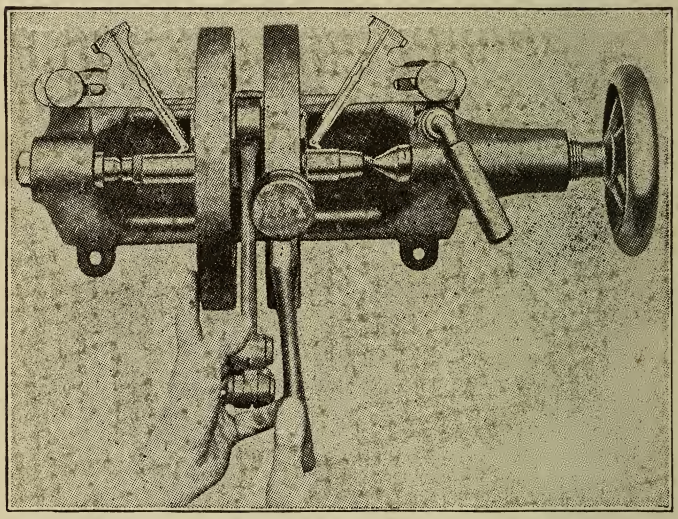

Figure 176.—Truing Crankshafts. (Courtesy of Harley-Davidson Motor Co.)

at the same time, that is, one of them should not be made absolutely true before work is begun on the other one because truing the second shaft will very often throw the first one out of line. After the shafts have been properly aligned, the assembly must be handled with great care until it is mounted in the crankcase.

THE CRANKCASE

The crankcase of the motor cycle engine should never be taken apart unless it is necessary to do so in order to make repairs. The halves of the crankcase are very carefully fitted to make an oil-tight joint. They should not be wedged apart because such practice will damage the machined surfaces and will probably result in an oil leak.

When the flywheels with their shafts are mounted in the crankcase bearings it is necessary that the bearings be exactly in line with each other because otherwise the flywheel shafts which have already been carefully lined up, will bind and cause a great loss of power.

The two halves of the crankcase should be put on over the flywheel shafts and bolted together at several points. It should then be possible to turn the flywheels freely. If they are not free it will be necessary to line up the parts of the crankcase which carry the bearings. This is done by passing a lining-up bar through one bearing and to the other, using special bushings in the work. When it is thus found in which direction the bearings are out of line the bar is partly withdrawn and the crankcase is slightly sprung as shown in Fgure 177. It may sometimes be necessary to ream the crankcase bushings as shown in Figure 178.

After the flywheel shafts have been fitted into the crankcase bearings the halves of the case are again removed and, their joints having previously been cleaned thoroughly, these joints are reshellaced, the gasket is put in place, the parts are reassembled, and finally bolted together. If the old gasket was un-

broken it will not be necessary to replace it with a new one.

When a motor cycle engine is assembled, all of the parts must move with perfect freedom. An engine

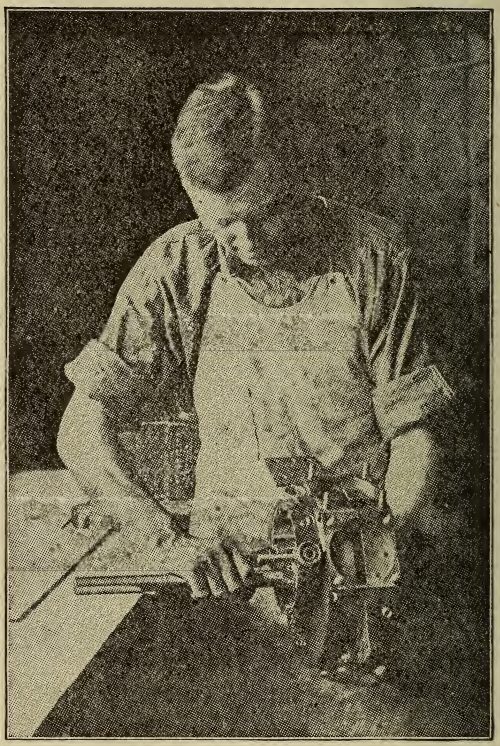

Figure 177.—Truing Crankcase Bushings. (Courtesy of Harley-Davidson Motor Co.)

should never be put into use with any of the parts binding even in the slightest degree as might be allowable in the case of an automobile engine. Motor cycle engines run at extremely high speeds and be-

cause of this fact neither looseness or binding is permissible.

VALVES

The valves and the valve mechanism are subjected to many forms of trouble. While making an exam-

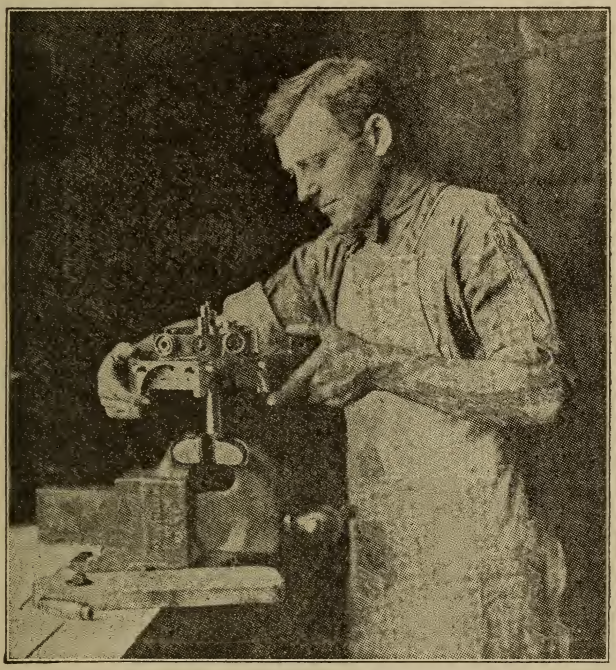

Figure 178.—Reaming Crankcase Bushings. (Courtesy of Harley-Davidson Motor Co.)

ination of this part of the engine it should be noted whether either the inlet or exhaust valves tend to stick or bind in some positions. If this condition is found it is probably due to bent stems or to an ex-

cessive accumulation of carbon. Stems can be tested for straightness by rolling them along a perfectly flat surface. A valve stem should have only sufficient clearance in its guide to allow it to work easily. The proper clearance for an inlet valve stem is about two-thousandths of an inch while the clearance for the exhaust valve stem can be four- or five-thousandths. If the guide or the valve stem is badly worn there will be an air leak and the mixture will be affected.

The valve stem, the valve face, and the seat in the cylinder should all be examined to see that no shoulders or ridges have been formed because this would result in holding the valve off its seat under some conditions. Should the engine have been run very hot at any time it is quite possible that the valve head and the upper end of the stem may have been warped.

In making an examination of the valve operating parts, such as shown in Figure 179, it should be seen that none of them stick and that there are no flat or binding rollers. If the guides for the valve-lifters are badly worn the engine will be noisy.

The meshing of the timing gears determines the valve timing and the correct position is usually indicated by corresponding marks on or between the teeth of the large and small gear, these marks when registering with each other bringing the gears into proper relation.

Compression.—Lack of compression in an engine almost always indicates that the valve faces and seats are pitted or carbonized and that they need grinding or refitting. The compression may be tested by slowly cranking the engine and by noting the resistance to

turning that is encountered during two full revolutions. As each cylinder is brought to its compression stroke, there should be a considerable increase in the effort required to operate the starter and at each of these points there should be a springiness due to the

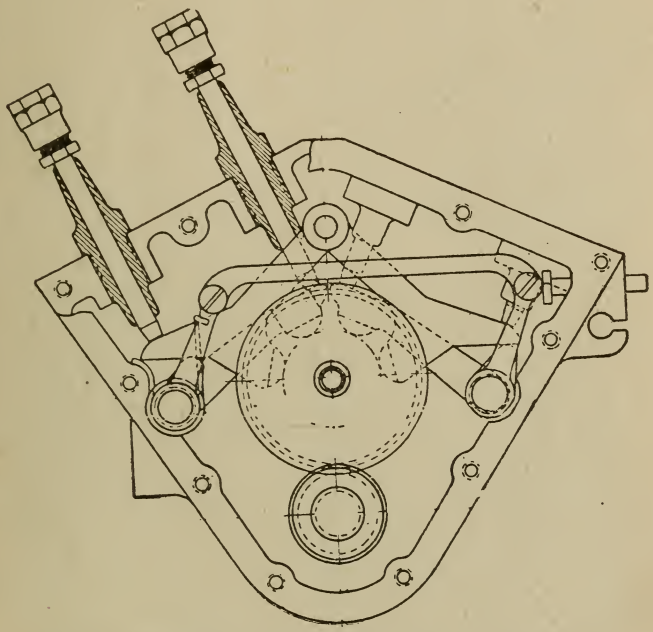

Figure 179.—Valve Lifter Adjustments (Precision).

compressed gas in the cylinder. It should be possible to crank through a part of a revolution several times and to have the starter spring backward each time pressure is released. In case points of compression seem to be passed without any great resistance, it will probably be necessary to grind the valves.

The trouble may be located in a certain cylinder by removing the spark plugs or by opening the pet cocks of the others. Each cylinder may be tested in this manner and if one of them allows the engine to

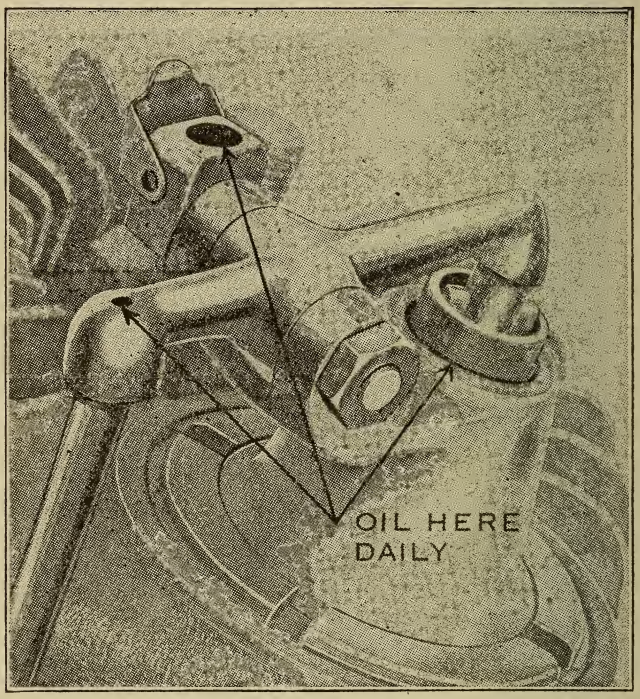

Figure 180.—Point at Which Oiling Prevents Wear of Valve Mechanism (Harley-Davidson).

be turned through two revolutions with little or no resistance, that cylinder is losing compression.

Loss of compression does not always result from a poor valve seating because such leakage may come

from loose spark plugs, loose priming cups, scored cylinders, poorly fitted rings, and similar faults.

Valve Grinding.—If the engine has its valves in side pockets with a valve cap and screw plug directly above the valve, it may be possible to insert a screw driver or a forked rod through the spark plug or pet cock opening in the valve cap and turn the valve on its seat through several revolutions. The valve face is polished by this turning, and any small particles of carbon may possibly be removed so that regrinding will be made unnecessary.

If, after polishing the valves by turning them on their seats only a slight leak of compression remains, the engine may be run for several days with the valve lifter adjusted quite loose. This excessive clearance will allow the valves to pound into place on their seats and will very likely result in a return of normal compression.

Removing the Valves.—Two principal types of valve mounting are employed. The valves may be in side pockets and covered by plugs or caps above them, as in Figure 181. By removing these caps the valves may be withdrawn through the top of the cylinder. Overhead valves are placed in cages which are themselves removable, while the springs are still carried by the cages.

With engines having pocketed valves it will be necessary to remove the valve spring from around the stem by methods whose exact application is determined by the construction used. It may sometimes be found that the cages of overhead valves resist attempts to remove them from the cylinder casting. In such an event it will be best to pour a liberal quantity of kerosene around the cage before using

any amount of force to pull it out of place. A light hammer tap on the upper end of the valve stem while the spring is still in place may loosen the cage sufficiently for it to be taken out.

Refacing and Reaming.—If the valve face has become concave due to excessive wear or to a great number of grindings, or if the face is found to be very badly scored or pitted, it will be next to impossible to secure good results by simple grinding. In this case the valve should be replaced with a new one or else the old one should have a new face made at the proper angle by placing it in a lathe or refacing tool and removing a slight cut.

Should the valve seat be found badly scored or pitted, or should it have assumed a convex form, it will be necessary to restore the correct seating by means of a reamer constructed for this work and used as shown in Figure 182.

When using the reamer it may be found that the teeth do not cut when the tool is first put into action. This is because it may be very difficult to force the reamer through the scale that has been burned onto the valve seat. If a slight additional pressure is exerted on one side of the reamer, that is, if the tool is tipped, the scale can be cut through with one revolution. The work is finished by giving the reamer a few turns under light pressure.

Grinding Methods.—After the valve has been removed and cleaned ready for grinding, it is necessary to use a very small quantity of valve grinding compound applied to the face of the valve with the finger tip or a knife blade. It is usually best to use the fine grade such as recommended for finishing.

A short length of light-weight coil spring should

be placed around the valve stem and brought up against the head. With the spring in place and the compound evenly distributed over the face, the valve may be dropped back into place so that it rests on its

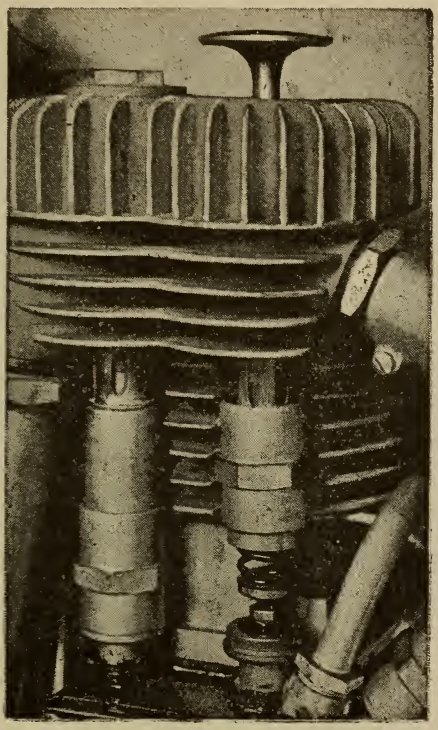

Figure 181.—Removing Pocketed Valve (Indian).

seat. The coil spring is used so that the valve face may be allowed to rise from the seat at intervals during the grinding operation.

By means of a screw driver or forked rod, or some

other tool specially designed to fit into openings or to fit projections on top of the head, the valve should be rotated through a part of a turn in one direction, then through a part of a turn in the opposite direction while pressing very lightly on the valve grinding

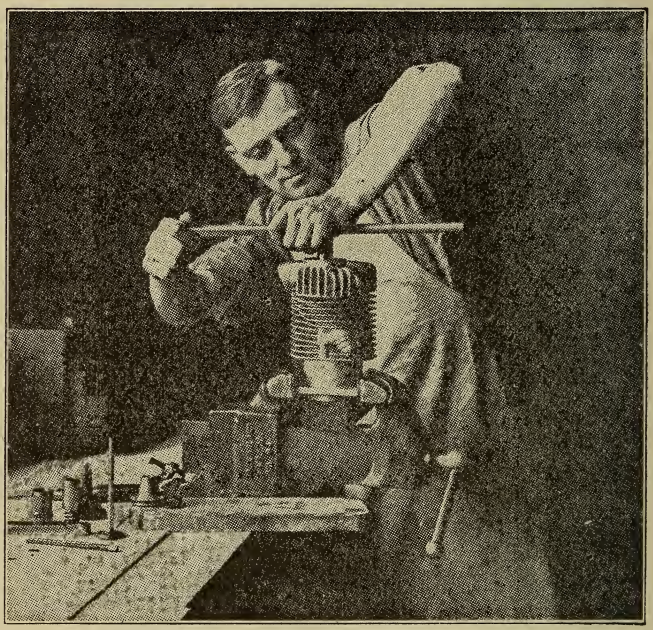

Figure 182.—Reaming Valve Seat. (Courtesy of Harley-Davidson Motor Co.)

tool. A light pressure will avoid pushing the grinding compound from between the face and the seat and will save a great deal of time. This turning back and forth should be continued for several minutes, after which the valve may be removed and the head washed with gasoline. If both the seat and the face

appear a clean, even, silvery grey, the work is finished; but if dark spots or pit marks still show, more of the grinding compound should be placed on the valve and the operation repeated. Grinding should not be continued after the valve seat and face appear clean because any further action only results in making the faces and seats oval in place of a straight taper.

Replacing the Valve.—The valve stems, the threads of valve caps, and the surfaces of valve cages, should be well covered with graphite grease or with a mixture of graphite and oil before being finally put into position. The recess into which the valve cage fits should be cleaned of any accumulations of carbon or thickened oil. Care should be used to place each valve back into its original position, also to avoid interchanging exhaust valve springs with inlet valve springs. In some engines the same strength of spring is used for both valves, yet this may not always be so and it will be best to use care in replacement.

After the work of valve grinding is completed, clearance between the bottom of the stem and the valve lifter should be measured and readjusted if necessary.

VALVE CLEARANCE

There is always a slight space allowed between the bottom of the valve stem and the top of the lifter which operates against the stem. Were there no clearance at this point, any slight variation in expansion of the valve when heated might cause it to remain off the seat and to allow escape of the compressed or the burning gas.

Because of the great heat to which the exhaust valve

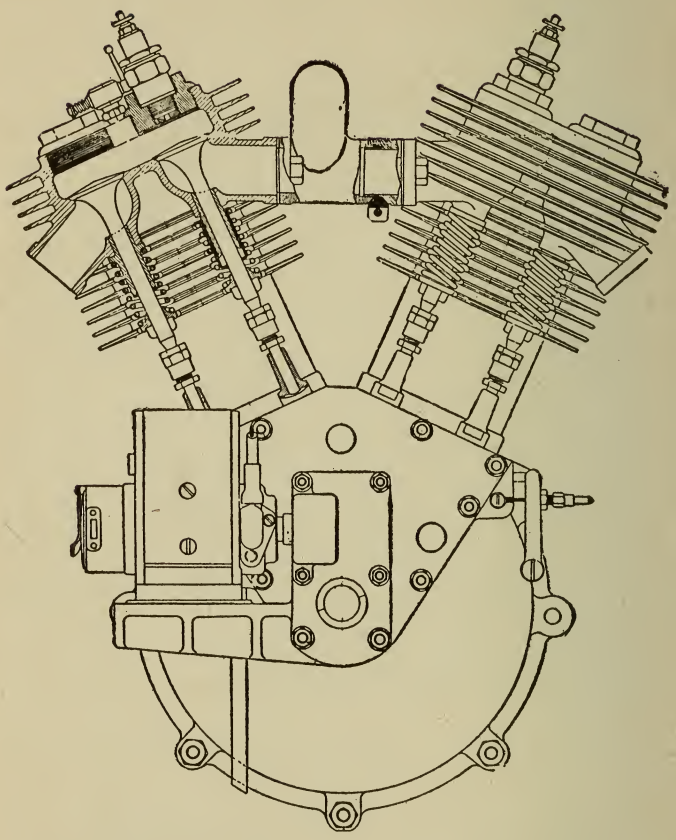

Figure 183.—Valve Spring Mountings and Valve Adjustments (Precision).

is subjected, it undergoes considerable expansion and the stem lengthens after the engine becomes hot. The exhaust valve and the cylinder itself expand to just about the same degree when heated and the clearance between the exhaust valve stem and its lifter will undergo little if any change between hot and cold conditions. On the other hand, the inlet valve is in an almost continuous stream of cool incoming gas. The cylinder expands when hot so that the valve seat in the cylinder is farther away from the crankcase and valve operating parts while the engine is running than it is when the engine is cold, but as the inlet valve, remaining cool, does not expand to any great extent, the clearance between the inlet valve stem and its lifter will become greater as the engine becomes warmer.

Clearance adjustments are generally made with a cool engine and it will be seen, according to the explanation just given, that the exhaust valve clearance should be set at the amount that is desired for running, while the inlet valve clearance should be made less than the amount desired for running. It is not best to attempt adjustment of either valve with a hot engine but this caution applies especially to the exhaust valve because a correct setting is difficult to secure while the parts are heated.

The clearance is measured in thousandths of an inch. The average setting for the inlet valve is from four to six thousandths (.004 to .006). The average setting of the exhaust valve clearance is from six to ten thousandths of an inch (.006 to .010). If the exhaust valve clearance is made too small, the engine will have a tendency to gallop, while if the clearance is made extremely great, the valve-lifters may be

somewhat noisy. Noise, however, is more generally caused by loose and worn parts than by excessive clearance for it has been found that a clearance as great as twelve to fifteen thousandths of an inch will give good results.

Certain precautions are necessary in adjusting the clearance of overhead valves which are operated by push rods and rockers. It will be realized that there are a number of points in this kind of mechanism at which there may be some slack or play and it is therefore necessary when measuring the clearance to press down on the push rod end of the rocker arm so that the total clearance will occur between the valve end of the rocker arm and the end of the valve stem. In some engines there is a light spring at the bottom of the push rod, this spring being designed to keep the moving parts in close engagement. Care should be used not to confuse the tension of this extra spring with tightness of the valve clearance.

When adjusting the clearance, loosen lock nuts slightly so that the adjusting screw can just be turned, but leave the nut tight enough to keep a pull on the parts.

Valve Springs.—Faulty operation of the engine may be due to weakened valve springs and in any event it is good practice to replace the old springs with new ones every two or three thousand miles. The valve springs may be tested for strength by inserting a screw driver blade between adjacent coils while the engine is running. Turning the screw driver edgeways will temporarily increase the spring tension. If the engine runs better with the additional tension it will be necessary to replace the spring or to strengthen it.

If the valve spring is found to be more than a quarter of an inch shorter than a new spring it should be replaced. If the spring has only lost about one-eighth of an inch in length it may be strengthened with a washer. It should be noted that exhaust valve springs are usually heavier than inlet springs, especially when an inlet valve is of the overhead type. The exhaust spring is made about fifty per cent stronger than the inlet.

Valve Cages.—Overhead valves are carried in a cage which supports the valve and its spring. The cage is then mounted in the cylinder casting. When a caged valve is to be ground the work can be most easily done by catching the end of the valve stem in a vise and then rotating the cage between the hands during the grinding operation.

It is necessary that the valve cage make a perfectly tight joint with the cylinder casting and this usually requires that the cage be ground into place whenever it has been removed. This grinding requires the use of only a very little compound and the work should be continued only long enough to clean the surfaces and make them a good fit. Sometimes it will not be necessary to use any grinding compound.

After the cages are fitted both the cage and cylinder recesses should be thoroughly cleaned of all traces of grinding compound. The shoulders which come in contact should be covered with a thin coating of graphite and oil. When the cage is put in place it should be turned around to distribute its graphite and oil, then brought into its proper position and fastened.

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